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MASSACHUSETTS AGRICULTURAL COLLEGE

THIRTY-SIXTH ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

REPORT OF THE DIRECTOR FOR THE FISCAL YEAR ENDING NOV. 30, 1923, PUBLISHED IN ACCORDANCE WITH THE PROVISIONS OF SECTION 32 OF CHAPTER 30 OF THE GENERAL LAWS

Publication of this Document approved by the Commission on Administration and Finance

DEPARTMENT OF EDUCATION
THE COMMONWEALTH OF MASSACHUSETTS

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Lewell S. Walker, B.Sc., *Assistant Official Chemist, Fertilizer Control.*
Frank J. Kokoski, B.Sc., *Analyst, Feed and Fertilizer Control.*
—— ——, *Analyst, Fertilizer Control.*
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Miss Hazel M. Parker, *Laboratory Assistant, Poultry Disease Elimination.*
Miss Rebecca L. Mellor, *Clerk, Poultry Disease Elimination.*

REPORT OF THE DIRECTOR.

SIDNEY B. HASKELL.

NEW WORK INSTITUTED.

The Legislature of 1923 made provision for three additions to the staff of the Experiment Station,—assistant research professors in Agronomy and in Vegetable Gardening, and an investigator at the Cranberry Station. Since funds to care for these new positions did not become available until September 1, little more could be done than to initiate the different phases of work for which these additional staff members were employed.

At the Market Garden Field Station was instituted an investigation entitled "A Study of the Factors Influencing the Heading of Greenhouse Lettuce." This project will be of service to greenhouse lettuce growers. Winter lettuce has until recently been a main crop in the greenhouse industry of the State. Competition of out-door lettuce from California has, however, been very serious, and in some cases has caused the closing of the greenhouse for the winter season. The problem, therefore, resolves itself into an attempt to develop ways and means by which the heading of greenhouse lettuce, grown during the short days of midwinter, may be controlled. There are three main lines of attack: first, through the use of artificial light to lengthen the growing day; secondly, through control of nutrient conditions; third, through breeding lettuce suited to the abnormal conditions of deficient sunlight.

The department of Agronomy has undertaken a comprehensive study of the effect of cropping systems on the growth and development of stalk-cut tobacco. This work will take some years to complete, for despite the fact that need for this study became apparent about a quarter of a century ago, very little has been done. In developing plans for this research, the Connecticut Experiment Station has given significant assistance. It is, in fact, essential that Massachusetts and Connecticut co-ordinate their studies, for the problems in the two states are much the same.

An intensive study of onion thrips control was instituted during the year. This insect has caused serious damage to the onion industry of the Connecticut Valley. During the past two or three years it has been particularly damaging. The results of the first year's study are highly encouraging, for they have demonstrated that a certain degree of control is at least possible, even though somewhat costly.

A survey of current practice in feeding of garbage to hogs was instituted during the year and carried through to successful completion. Mr. Glatfelter of the College had charge of the work. This was most productive in showing that, on account of the varied nature of the industry, a formal study of this problem is impracticable.

On account of the change in work brought about by the retirement of Dr. Goodale and the taking over of this work by Dr. Hays, the projects in Poultry Husbandry were reformulated. The old projects are still being carried on, and in addition three new projects, respectively on "A Genetic Study of Rhode Island Red Color", "Determination of Genetic Laws Governing Results in Inbreeding of Poultry" and "The Hatchability of Eggs", all under the immediate direction of Professor Hays, have been undertaken. These are based largely on records made during the ten years over which the poultry breeding work of the Experiment Station has been continued. As time goes on the data so painstakingly collected will be increasingly valuable.

Other new work undertaken during the year includes a vegetation test to study the availability of the nitrogen in certain grades of mixed fertilizers, under the immediate direction of Mr. Haskins of the Fertilizer Control Service; and, in co-operation with the United States Department of Agriculture, a study of fruit harvesting and storage, under the immediate direction and leadership of Mr. Raleigh of the College Department of Pomology. The Department of Veterinary Science and Animal Pathology has instituted a fundamental study of bacteriophagic specificity with special reference to *B. pullorum* infection and therapeusis, with Dr. Pyle in charge.

A preliminary study of the immediate effect of fertilizer as applied in varying quantities on the germination of onion seed was carried through. Despite the fact that this work indicated occasional delay in germination through the use of large quantities of chemicals, it will not be continued in 1924. The conditions under which the work was carried on are not such as to warrant its continuation.

An indicative feeding test, without formal project organization, has been under way for some months, in testing the value of hydrolyzed sawdust for dairy stock. This work is in co-operation with the Forest Products Laboratory of the United States Department of Agriculture, and supplements work being done in other parts of the country. The indications are that sawdust treated in the way indicated has a definite food value, and that a definite project study of the problem should be undertaken.

MORE IMPORTANT RESULTS OF THE YEAR'S WORK.

Definite proof of the fact that higher food costs of Massachusetts are due to factors within the control of the State, rather than to either the geographical location of the State or the amount of agriculture in the State, was developed in the prosecution of Dr. McFall's project "Boston Food Supply Study." The wholesale costs of food in Massachusetts are but slightly higher than in other competing states. Over against this is the fact that the retail costs of food are from 14 to 17 per cent higher, on an average of costs in a weighted dietary, than in other competing sections. Somewhere in the costs incident to the handling, sale and distribution of food within the State are costs apparently not incurred in the same degree in other sections. This, however, must be considered as merely the starting point for further investigation.

There has been continued progress in the nursery certification work, organized under the Massachusetts Fruit Growers' Association, and based on Dr. Shaw's study, "Tree Characters of Fruit Varieties." About 65,000 nursery trees were certified. This work is not properly experimental, despite the fact that it is a charge against research funds. The only apparent way in which the research studies thus far made can be used to good advantage is in continuing the work until men and organizations can be trained to give service in certification of varieties. Sufficient progress should be made by another season to permit of the Station withdrawing from this commercial service phase of the investigation.

From the Market Garden Field Station as well as from other experiments in Amherst, have come some rather striking contributions to the ever-present problem of fertility maintenance. At both places there have been certain areas of land which have been maltreated over a period of years; in the one case for more than a generation, in the other since the Field Station was first started in 1918. The significant fact developed is that, even when the producing power of the soil drops to a low level through neglect or maltreatment, injury is not permanent. At the Market Garden Field Station areas of land unfertilized for five years, but this last year receiving a heavy application of chemical fertilizers, gave crops nearly as good as those receiving normal treatment. At the home station, the depressing effect of past one-sided fertility treatment was overcome in a single season by what may be called a normal optimum application of manures and fertilizers.

The work carried on in the eastern part of the State during the past three seasons on the control of apple scab has been brought to a successful and satisfactory conclusion. Professor Webster S. Krout was originally in charge of this investigation, more lately his successor Professor William S. Doran. The co-operation extended to the Station by the Nashua Fruit Growers' Association, and by the Farm Bureaus of Worcester and Middlesex Counties was extremely gratifying. The same may be said of the co-operation of those individual fruit growers who placed their orchards at the disposal of the Experiment Station for spraying investigations, and who in other ways co-operated to make the work successful. As a result of this effort, the fact that the destructive apple scab may be controlled, and at an expense but slightly greater than that ordinarily incurred without such control has been convincingly demonstrated.

Another interesting and valuable piece of work which has yielded concrete results is that carried on by Mr. Worthley in his study of the control of the squash vine borer. For years this insect has served to decrease local interest in the production of squashes and to increase the cost of this vegetable regardless of where it was produced. The only methods of control suggested were unsatisfactory, and exceedingly expensive. By the new method the egg of this insect is killed, whereas most previous methods of attack had attempted to kill after the larva had worked its way into the stem of the plant and commenced its destructive attack.

The work in the breeding of poultry as established first by Dr. Goodale and carried on more recently by his successor, Dr. Hays, continues to bring striking and most important results. The building of a house for laying hens enables the Station to project its work to a later age period than was formerly possible. In this and many other ways the project promises even greater service in the future than has been given in the past.

The investigation of the natural vegetation on permanent pastures, as conducted on the Tillson Farm, has given most valuable data. These permanent pastures should be the backbone of the Massachusetts dairy industry. So depleted have they become, however, during the years of continuous pasturage, and so foul with weeds of many different kinds, that many are now liabilities rather than assets. On the Tillson Farm pasture, however, on land not plowed for a generation, perhaps never, the natural vegetation of running cinquefoil, hairy cap moss and other weeds has been absolutely replaced by a perfect carpet of white clover, without plowing or reseeding. The application of these results to pastures in different parts of the State is still an open question. This work, coupled with demonstrational work carried on over a period of several years by the department of Agronomy of the Extension Service, gives a starting point for the improvement of such of our permanent pastures as have not already degenerated into brush lots or open woodlands.

The year's work on onion diseases, carried on under the leadership of Dr. Anderson, concerned itself particularly with control of the onion smut through the use of formaldehyde and other products. There was striking demonstration of the value of repeated experiments. That formaldehyde properly applied prevents smut, even on badly infested land, has long been known. That under certain conditions the formaldehyde may injure germination is a comparatively recent discovery. It therefore became necessary for the Station to determine conditions under which injury from treatment might be more serious than benefit from the use of formaldehyde. The season's work showed that moisture conditions at the time of planting had a dominant effect; and that the formula of concentration and rate of application must be varied on the basis of moisture conditions in the soil at time of planting.

CAPITALIZATION OF STATION WORK.

These few scattered instances of some of the more significant results of the year's work indicate the varied ways in which the State capitalizes the agricultural research of its Experiment Station. A part goes directly to farmers and is used by them. This is particularly true of that work which develops methods of controlling injurious insects, and plant or animal diseases. In the case of the investigation of the white diarrhœa of poultry, however, it was necessary to organize a State control in order that this research work might be made of service to practical poultrymen. Again, it may be necessary to seek a commercial outlet. The plan for the certification of nursery stock is a case in point. Much of the work of the Experiment Station finds its first field of usefulness in contributing facts leading to the solution of fundamental problems of agriculture and agricultural welfare. This is particularly true of certain of the chemical and biological investigations of soil fertility, carried on the past few years, and with certain types of economic studies. With increasing separation of research and extension teaching, it is probable that greater attention must be given to the capitalization of agricultural research in those particular fields where it is found most valuable.

CHANGES IN STATION STAFF, DECEMBER 1, 1922 TO DECEMBER 1, 1923.

During the year there were five resignations from the Station service.

Mr. Raymond W. Swift, analyst in the Control Service, resigned to accept a position with the Pennsylvania State Bureau of Animal Nutrition. This change represented a distinct advance and increased opportunity for Mr. Swift. His service here had been eminently satisfactory.

Professor Webster S. Krout, assistant research professor of Botany, and in charge of apple scab investigations in the eastern part of the State, submitted his resignation April 15, 1923, to enter the Extension Service of the Pennyslvania State College. Mr. Krout first entered the service of the Experiment Station in April, 1917, and during his six years of service with the Station made an enviable reputation along research lines. He was particularly successful in organizing the co-operative work on apple scab control in the eastern part of the State. It was with great regret that his resignation was accepted.

At the end of August, Miss Mildred H. Hollis, laboratory assistant in Poultry Disease Elimination, submitted her resignation. While she had been with the Station for but a year, her work had been highly satisfactory.

Miss Doris Tower, Clerk in the department of Poultry Husbandry, resigned to accept a position in the department of Poultry Husbandry, Kansas Agricultural

College, Manhattan, Kansas. Miss Tower had been with the department for four and one-half years, and had become most efficient in its work.

On November 21, Mr. S. J. Broderick, who entered the service of the Station in January, 1923, to take the place left vacant by Mr. Swift, submitted his resignation, to enter into commercial work.

On January 31, Mr. Arthur P. French, who had been investigator in Pomology for a year and a half, left the Station service through transfer to the teaching force of the College.

The large number of resignations among the more poorly paid members of the staff indicates that in our present salary schedule the Station is not keeping pace with the growth of its men in ability and productiveness. This matter, as was pointed out in a report to the president, submitted in December, 1922, is vital to the welfare of the Station and the work which it represents, and should have definite trustee study.

Appointments to fill positions made vacant by resignations include that of Professor William L. Doran, assistant research professor of Botany, to have charge of the pathological work on fruits and vegetables in the eastern part of the State. Mr. Doran is a graduate of the College in the class of 1915, and received the degree of Master of Science in 1917. He comes to the service of the Station after making an enviable record in his chosen science at the New Hampshire Agricultural Experiment Station.

Miss Alice J. Twible was appointed clerk in Poultry Husbandry to succeed Miss Tower.

Miss Hazel M. Parker was appointed to the position of laboratory assistant in Poultry Disease Elimination left vacant by the resignation of Miss Hollis.

Mr. John S. Bailey was appointed to fill the place made vacant by the transfer of Mr. French as investigator in Pomology.

New appointments include Mr. V. A. Tiedjens, assistant research professor of Vegetable Gardening, who is assigned to the experimental work at the Market Garden Field Station; Mr. John P. Jones, assistant research professor of Agronomy, who is undertaking studies in connection with the tobacco industry of the Connecticut Valley; and Mr. Donald S. Lacroix, investigator, assigned to the Cranberry Station.

PUBLICATIONS OF THE YEAR.

Annual Report.

Thirty-fifth annual report:

Part I. Report of the Director and other Officers.
Part II. Detailed Report of the Experiment Station (Bulletins 207–212).
Combined Contents and Index, Parts I and II.

Bulletins.

No. 213. Tobacco Wildfire in 1922, by P. J. Anderson and G. H. Chapman.
No. 214. Combating Apple Scab. Spraying and Dusting Experiments in 1922, by Webster S. Krout.
No. 215. Pedigree, the Basis of Selecting Breeding Males for Egg Production, by F. A. Hays and Ruby Sanborn.
No. 216. Digestion Experiments with Cattle Feeds, by J. B. Lindsey, C. L. Beals, P. H. Smith and J. G. Archibald.
No. 217. The Value of Buttermilk and Lactic Acid in Pig Feeding, by J. B. Lindsey and C. L. Beals.
No. 218. The Control of the Squash Vine Borer in Massachusetts, by Harlan N. Worthley.

Bulletins, Popular Edition.

No. 216. The Feeding Value of Some Unusual Commercial Feeds, by J. G. Archibald.

Bulletins, Control Series.

No. 23. Control of Bacillary White Diarrhœa, 1922–1923, by G. E. Gage and O. S. Flint.
No. 24. Inspection of Commercial Feedstuffs, by Philip H. Smith and Frank J. Kokoski.

No. 25. Inspection of Commercial Fertilizers, by H. D. Haskins, L. S. Walker, and S. J. Broderick.
No. 26. Inspection of Lime Products Used in Agriculture, by H. D. Haskins, L. S. Walker, and S. J. Broderick.

Meteorological Reports.

Nos. 409–420 inclusive.

Scientific Contributions.

No. 1. Inbreeding the Rhode Island Red Fowl with Special Reference to Winter Egg Production, by F. A. Hays. *In* American Naturalist, Vol. LVIII, No. 654, January–February, 1924.
No. 2. A Study in the Control of Poultry Diseases, by John W. Lentz. *In* Poultry Science, Vol. II, December–January, 1922–23.
No. 3. Tests of Low Lift Pumps, by C. I. Gunness. *In* Agricultural Engineering, Vol. 4, No. 3, March, 1923.
No. 4. An Improved Formaldehyde Tank for the Onion Drill, by P. J. Anderson and A. V. Osmun. *In* Phytopathology, Vol. XIII, No. 4, April, 1923.
No. 5. Relations between Calcium Carbonate, Certain Fertilizer Chemicals and the Soil Solution, by F. W. Morse. *In* Soil Science, Vol. XV, No. 2, February, 1923.
No. 6. Control of Lettuce Drop by the Use of Formaldehyde, by Webster S. Krout. *In* Journal of Agricultural Research, Vol. XXIII, No. 8, February 24, 1923.
No. 7. The Squash Bug in Massachusetts, by H. N. Worthley. *In* Journal of Economic Entomology, Vol. 16, No. 1, February, 1923.
No. 8. Methods of Distribution of Phosphorus Fertilizers, by S. B. Haskell. *In* Journal of the American Society of Agronomy, Vol. 15, No. 4, April, 1923.
No. 9. An Experiment in Ringing Apple Trees, by J. K. Shaw. *In* Proceedings of the American Society of Horticultural Science, 1922.
No. 10. A Study of Bearing Habit of Apple Varieties, by W. B. Mack. *In* Proceedings of the American Society of Horticultural Science, 1922.
No. 11. Determination of Fatty Acids in Butter Fat: II, by E. B. Holland *et al.* *In* Journal of Agricultural Research, Vol. XXIV, No. 5, May 5, 1923.
No. 12. Influence of the Plane of Nutrition on Susceptibility to Injury from Toxic Concentrations, by F. W. Morse. *In* Journal of the American Society of Agronomy, Vol. 15, No. 7, July, 1923.
No. 13. Physiological Study of Azotobacter Chroococcum, Beijerinckii and Vinelandii Types, by Unokichi Yamagata and Arao Itano. *In* Journal of Bacteriology, Vol. VIII, No. 6, November, 1923.
No. 14. Physiological Study of Azotobacter Chroococcum. I. Influence of Vitamine B (?) and Nucleic Acid on Azotobacter, by Arao Itano. *In* Journal of Bacteriology, Vol. VIII, No. 5, September, 1923.
No. 15. The Relation of Soil Moisture to Formaldehyde Injury of Onion Seedlings, by P. J. Anderson. *In* Phytopathology, Vol. XIII, No. 9, September, 1923.
No. 16. Determination of Sulphur Compounds in Dry Lime-Sulphur, by Carleton Parker Jones. *In* Journal of Agricultural Research, Vol. XXV, No. 7, August 18, 1923.
No. 17. Comparative Effects of Muriate and Sulfate of Potash on the Soil in a Long Continued Fertilizer Experiment, by F. W. Morse. *In* Soil Science, Vol. XVI, No. 2, August, 1923.
No. 18. Farm Ownership in Massachusetts, by Lorian P. Jefferson. *In* Journal of Farm Economics, Vol. V, No. 4, October, 1923.
No. 20. Agricultural Research in its Service to American Industry, by Sidney B. Haskell. *In* Journal of the American Society of Agronomy, Vol. 15, No. 12, December, 1923.
No. 21. Notes on the Cape Cod Brood of Periodical Cicada During 1923, by D. S. Lacroix. *In* Psyche, Vol. XXX, No. 6, December, 1923.

REPORT ON PROJECTS.

Projects Completed.

During the year ten projects were completed, as follows:

Agriculture 1. Comparison of nitrogenous fertilizers. *Assistant Professor Gaskill.*
Animal Husbandry 2. Survey of garbage feeding plants in Massachusetts. *Assistant Professor Glatfelter.*
Botany 10. Apple disease control investigations. *Assistant Professor Doran.*
Chemistry 2. Digestion experiments. *Professor Lindsey and Assistant Professor Archibald.*
Chemistry 5. Chemistry of arsenical insecticides. *Professor Holland and Mr. Dunbar.*
Chemistry 6. Lime absorption and acidity of Field A. *Professor Morse.*
Chemistry 7. Effects of sulfate and muriate of potash on the soil of Field B. *Professor Morse.*
Chemistry 12. Attempting to improve the nutritive value of grain hulls. *Professor Lindsey and Assistant Professor Archibald.*
Chemistry 18. To determine the mineral constituents of forage crops. *Professor Lindsey and Assistant Professor Archibald.*
Fertilizer Control 1. Vegetation tests to study nitrogen availability. *H. D. Haskins, Official Chemist.*

In most of the above cases final report has been made, although publication may be delayed until other related work is completed.

Projects Transferred to the Inactive List.

Owing to the inability of the Station to give adequate financial support, the following projects have been transferred to the inactive list:

Botany 5. Study of plant stimulation by formaldehyde.
Chemistry 3. Summer forage crops.
Entomology 2. Economic importance of digger wasps.
Entomology 3. Control of the onion maggot.
Microbiology 1. Microbiological investigations in milk.
Microbiology 3. Canning investigations.

Projects Discontinued.

The Station policy of submitting every project of record to critical analysis of a committee has resulted in certain projects being discontinued, because of unsatisfactory operating conditions. Variation in the soil, inability to secure adequate machinery, lack of personnel — any one of these may be a contributing cause. Based upon recommendations of committees, the following projects have been discontinued:

Agriculture 4. Methods of applying lime and quantity of application.
Agriculture 6. Top-dressing permanent grasslands.
Agriculture 8. Determination of effect of fertilizer on the germination of onion seed.
Botany 12. Potato spraying versus dusting in the control of late blight.
Market Garden Field Station 4. Variety and strain tests of tomatoes.
Market Garden Field Station 5. Growth control by means of intercropping.

Catalog of Active Projects, December 1, 1923.

Plant Nutrition and Soil Fertility.

Chemical Investigations.

Chemistry 14. A study of the availability of soil potash, with the object of developing a system of diagnosis for soils of the State. *Professor Morse.*

Microbiological Investigations.

Microbiology 2. Soil fertility as influenced by micro-organisms in their relation to the presence and disappearance of organic matter. *Assistant Professor Itano and Mr. Sanborn.*

Physiological Studies.

Botany 1. Optimum conditions of light for plant response. *Assistant Professor Clark.*

Market Garden Field Station 7. Study of the factors influencing the heading of greenhouse lettuce. *Assistant Professor Tiedjens.*

Pomology 1. The interrelation of stock and scion in apples. *Professor Shaw and Mr. Bailey.*

Pomology 12. Apple variety fruit spur study. *Professor Shaw, Assistant Professor Van Meter, and Assistant Professor C. P. Jones.*

Pomology 14. Winter injury of brambles. *Professor Shaw, Assistant Professor C. P. Jones, and Assistant Professor Clark.*

Soil Management and Fertilizer Tests.

Agronomy 2. Tobacco cropping system investigations. *Assistant Professor J. P. Jones and Professor Anderson.*

Agriculture 3. Residual value of excess phosphorus applications. *Assistant Professor J. P. Jones.*

Agriculture 7. An attempt to restore productive fertility to wornout and maltreated soils. *Assistant Professor Gaskill.*

Botany 13. Ecological study of pasture vegetation. *Professor Osmun and Director Haskell.*

Market Garden Field Station 1. Manure economy tests. *Professor Tompson.*

Pomology 5. Comparison of cultivation and sod mulch in a bearing orchard. *Professor Shaw.*

Pomology 6. Comparison of clover sod and grass in a sod mulch orchard. *Professor Shaw.*

Pomology 7. Test of fertilizers on a sod mulch orchard. *Professor Shaw.*

Pomology 8. Test of cover crops for apple orchards. *Professor Shaw.*

Pomology 15. Orchard fertilization. *Professor Shaw.*

Pomology 16. Tests of different amounts of nitrate of soda. *Professor Shaw and Assistant Professor Drain.*

Pomology 18. Comparison of cultivation and heavy mulching of apples and pears. *Professor Shaw.*

Pomology 19. A study of the effects of fertilizer limitations on fruit plants. *Professor Shaw.*

Pomology 20. Tests of fertilizers for pears. *Professor Shaw.*

Crop and Crop Management Studies.

Plant Introduction.

Cranberry 5. Blueberry investigations. *Professor Franklin.*

Pomology 17. Study of the cultivation of the high-bush cranberry. *Professor* Shaw.

Strain and Variety Tests.

Agriculture 5. Meadow fescue versus timothy. *Assistant Professor Gaskill.*

Agronomy 1. Investigation of the value of Hubam or annual sweet clover as compared with the biennial sweet clover. *Professor Michels.*

Pomology 2. Study of tree characters of fruit varieties. *Professor Shaw and Mr. A. P. French.*

Pomology 13. Studies of varieties of tree fruits. *Professor Shaw and Mr. Raleigh.*

Breeding and Crop Plant Improvement.

Market Garden Field Station 6. Improvement of Martha Washington asparagus. *Assistant Professor Tiedjens.*

Pomology 3. The genetic composition of peaches. *Professor Shaw and Mr. Bailey.*

Orchard Management.

Pomology 4, 9, 10. Experiments in pruning apples. *Professor Shaw.*

Harvesting and Storing.

Pomology 21. Study of fruit harvesting and storing. *Mr. Raleigh.*

Crop Protection.

Insect Enemies of Vegetation.

Entomology 4. Control of the squash vine borer. *Mr. Worthley.*

Entomology 5. Control of the squash bug. *Mr. Worthley.*

Entomology 7. Study of insect outbreaks in various localities. *Professor Fernald.*

Entomology 8. Pest limits in Massachusetts. *Professor Fernald.*

Entomology 9. Number of generations of codling moth in Massachusetts as related to advisability of spraying for the second generation. *Assistant Professor Bourne.*

Entomology 10. Hatching dates of scale insects. *Assistant Professor Bourne.*

Entomology 17. Control of onion thrips. *Assistant Professor Bourne.*

Cranberry 1. Injurious and beneficial insects affecting the cranberry. *Professor Franklin.*

Plant Disease Control.

Botany 3. Tobacco investigations. *Professor Osmun and Professor Anderson.*

Botany 9. Investigation of carrot blight. *Assistant Professor Doran.*

Botany 5. Experimental spraying for the control of cucumber mildew under glass. *Assistant Professor Doran.*

Botany 6. Investigation of onion diseases. *Professor Osmun and Professor Anderson.*

Botany 14. Investigation of control of tobacco wildfire. *Professor Anderson.*

Botany 16. Relation of soil character to occurrence of onion smut. *Professor Anderson.*

Cranberry 2. Cranberry disease work. *Professor Franklin.*

Spray Materials — Their Nature and Use.

Chemistry 20. A study of the fundamental factors affecting the suspension adhesiveness, toxicity and general efficiency of copper fungicides. *Professor Holland and Mr. Dunbar.*

Entomology 12. Determination of best strength of lime-sulfur. *Assistant Professor Bourne.*

Entomology 13. Study of the possible injurious effects of Scalecide on trees. *Assistant Professor Bourne.*

Entomology 14. Does spraying orchards kill bees? *Professor Fernald.*

Entomology 15. Determination of the efficiency of nicotine sulfate dusts. *Assistant Professor Bourne.*

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Chemistry 19. The value of inorganic calcium phosphate in the promotion of growth and milk production. *Professor Lindsey and Assistant Professor Archibald.*

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Chemistry 4. Record of the station herd. *Professor Lindsey.*

Poultry Husbandry.

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Poultry 1. Broodiness in poultry. *Professor Hays.*
Poultry 2. Breeding poultry for egg production. *Professor Hays.*
Poultry 3. A genetic study of Rhode Island Red color. *Professor Hays.*
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Meteorological Studies.

Entomology 11. Study of area of the late frosts as shown by insect distribution. *Professor Fernald.*
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CONTROL AND REGULATIVE SERVICE.

In addition to the conduct of agricultural research, the Station administers the State feed and fertilizer control laws, the law for the inspection of dairy glassware, and the poultry disease elimination law; and likewise, in co-operation with the different breed associations, conducts tests for advanced registry. With the single exception of the law relating to the elimination of certain poultry diseases, all of these control functions are self-supporting, are administered by separate staffs, and do not represent a drain on the research funds of the Experiment Station. Full report of the poultry disease elimination work is contained in Control Bulletin No. 23, published in September, 1923. The report on commercial feedstuffs is listed as Control Bulletin No. 24; that on fertilizers as Nos. 25 and 26, the last referring to lime products used in agriculture. In addition these different departments perform a large amount of analytical service for the Experiment Station as well as for certain agricultural organizations and others. Wherever service of this kind is for other than public or community benefit, a fee is charged.

In furtherance of the dairy law, so-called, 81 certificates of proficiency have been awarded, and inspections of apparatus and machinery made in 106 different places. Two machines were condemned and minor repairs ordered on 17. Reinspections were necessary in 6 places. Six thousand, one hundred and twenty-five pieces of glassware were calibrated, of which only 18 were condemned. The very low ratio of pieces of apparatus condemned to the total inspected demonstrates most strikingly the value of a control of this kind. In the first year of full operation under this law, 291 pieces of glassware, 5.77 per cent of the whole number inspected, were condemned.

The report on the advanced registry testing of dairy cows follows:

Summary of Two-Day Test Work, December, 1922, through November, 1923.

Number of Cows tested.

Month.	Number of Supervisors, Whole or Part Time.	Guernsey.	Jersey.	Ayrshire.	Shorthorn.	Holstein.	Totals.
December	12	200	111	96	12	119	538
January	12	215	105	94	13	53	480
February	12	206	113	91	15	74	499
March	12	228	123	99	16	93	559
April	15	217	113	84	16	99	529
May	11	218	86	83	18	103	508
June	10	235	101	88	23	95	542
July	10	236	92	89	24	99	540
August	10	237	99	91	24	90	541
September	10	241	84	76	20	90	511
October	9	226	87	66	25	99	503
November	9	235	91	70	23	101	520
Totals	–	2,694	1,205	1,027	229	1,115	6,270

Number of Herds visited.

Month.	Number of Supervisors, Whole or Part Time.	Guernsey.	Jersey.	Ayrshire.	Shorthorn.	Holstein.	Totals.
December	12	34	12	12	2	13	73
January	12	36	12	11	2	10	71
February	12	36	13	11	2	10	72
March	12	41	15	12	2	10	80
April	15	40	17	10	2	9	78
May	11	44	20	9	2	13	88
June	10	37	20	9	2	10	78
July	10	33	16	9	2	11	71
August	10	37	15	10	2	10	74
September	10	31	13	7	2	10	63
October	9	33	13	8	2	11	67
November	9	37	13	7	2	11	70
Totals	–	–	–	–	–	–	885

The total number of tests made during the year ending December 1, 1923, decreased by 1,172, compared with the previous year.

There were twenty men employed for the seven-day Holstein work, 38 farms visited, and 125 reports turned in.

DIAGNOSTIC AND ANALYTICAL SERVICE.

In addition to the service already reported the Station performs a large amount of diagnostic and analytical work. The department of Veterinary Science examines samples of diseased poultry sent in for examination, makes diagnosis and reports back to the sender. The department of Botany makes similar examinations of diseased plants submitted, and the department of Entomology diagnoses insect injury from such samples of either plant or insect as may be sent in. This work is all of it most important. It is not duplicated by any other agency in the State, and requires a very high degree of skill in its performance. It must be admitted, however, that it is a heavy drain on research funds, and that the same work must be repeated annually for different individuals or communities over a period of many seasons. For this reason the work would be more efficient if it could be organized under the Extension Service.

In the department of Plant and Animal Chemistry, many analyses are made of milks, creams, feedstuffs and other products submitted for examination. This work differs from the foregoing in that more is for the benefit of the individual and less for that of the State or a group of citizens within the State. For this reason a fee is charged for certain parts of this work. The same department has given most valuable service in co-operating with other Station departments through making analyses of soils, fertilizers, feeds, plants, insecticides and fungicides and other materials on which information was needed. The co-operative spirit in which this work has been done is most gratifying.

METEOROLOGICAL OBSERVATIONS.

Department of Meteorology.

PROF. J. E. OSTRANDER, HEAD.

Annual Summary for 1923.

Pressure (in Inches).

Maximum reduced to freezing	30.52, Jan. 22nd, 11 A.
Minimum reduced to freezing	28.98, Dec. 28th, 12 M.
Maximum reduced to freezing and sea-level	30.84, Jan. 22nd, 11 A.
Minimum reduced to freezing and sea-level	29.29, Dec. 28th, 12 M.
Mean semi-daily reduced to freezing and sea-level	30.020
Annual range	1.55

Air Temperature (in Degrees Fahr.).[1]

Highest	97.0, June 19th, 3 P.
Lowest	—12.0, Jan. 31st, 6 A.
Mean hourly	46.6
Mean of means of max. and min.	46.8
Mean sensible (wet bulb)	41.4
Annual range	109.0
Highest mean daily	81.7, June 20th
Lowest mean daily	3.8, Feb. 18
Mean maximum	58.5
Mean minimum	35.1
Mean daily range	23.4
Greatest daily range	49.0, Sept. 23d
Least daily range	3.5, Nov. 7th

Humidity.

Mean dew point	36.9
Mean force of vapor	.369
Mean relative humidity	75.5

Wind.

Prevailing direction	West, Northwest

Summary.

North	12 per cent
North Northwest	11 per cent
South	12 per cent
South Southwest	12 per cent
Northwest	12 per cent
Other directions	41 per cent
Total movement	48,864 m.
Greatest daily movement	405 m., Mar. 5th
Least daily movement	18 m., Nov. 16th
Mean daily movement	134 m.
Mean hourly velocity	5.6 m.

Maximum pressure per square foot, 22.5 lbs., = 67 m. per hour, Apr. 29th, 1 A., S. S. W.

Maximum velocity for 5 minutes, 36 m. per hour, Mar. 28th, 2 P., W. N. W.; Apr. 29th, 1 A., S. S. W.

Precipitation (in Inches).

Total precipitation, rain or melted snow	39.49
Snow total in inches	63.7
Number of days on which .01 or more rain or melted snow fell	125

Weather.

Mean cloudiness observed	45 per cent
Total cloudiness recorded by Sun Thermometer	1,686 hrs. = 38 per cent
Number of clear days	141
Number of fair days	131
Number of cloudy days	93

Bright Sunshine.

Number of hours recorded	2,773 hrs. = 62 per cent

Dates of Frosts.

Last	May 24th
First	Sept. 15th

Dates of Snow.

Last	April 15th
First	Nov. 8th
Total days of sleighing	86

Gales of 50 or More Miles Per Hour.

54 m. Feb. 3d, N. W.; 52 m. Mar. 19th, W. N. W.; 59 m. Mar. 28th, W. N. W.; 52 m. Apr. 24th, N.; 67 m. Apr. 29th, S. S. W.

[1] Temperature in ground shelter.

REPORT OF THE TREASURER.

FRED C. KENNEY.

United States Appropriations, 1922–23.

Dr.	Hatch Fund.	Adams Fund.
To receipts from the Treasurer of the United States, as per appropriations for fiscal year ended June 30, 1923, under Acts of Congress approved March 2, 1887 and March 16, 1906	$15,000 00	$15,000 00

Cr.

		Hatch Fund	Adams Fund
Adams:			
By salaries	$14,631 00		
tools and machinery, furniture and fixtures	20 25		
scientific apparatus	10 57		
seeds, plants and sundry supplies	5 95		
chemical and laboratory supplies	21 92		
labor	310 31		
	$15,000 00		$15,000 00
Hatch:			
By salaries	$12,980 00		
labor	1,442 13		
seeds, plants and sundry supplies	35 34		
livestock	35 00		
tools and machinery	52 25		
fertilizer	321 97		
chemical and laboratory supplies	133 31		
	$15,000 00	$15,000 00	

State Appropriations, 1922–23.

Cash balance brought forward from last fiscal year	–
Cash received from State Treasurer	$107,410 38
fees	37,522 41
sales	3,983 10
miscellaneous	424 39
	$149,340 28
Cash paid for salaries	$64,462 44
labor	15,962 03
publications	3,198 65
postage and stationery	2,375 96
freight and express	864 95
heat, light, water and power	1,105 72
chemicals and laboratory supplies	3,472 53
seeds, plants and sundry supplies	936 62
fertilizers	781 09
feeding stuffs	1,837 55
library	1,193 57
tools, machinery and appliances	2,224 75
furniture and fixtures	419 40
scientific apparatus and specimens	761 27
live stock	21 45
traveling expenses	5,398 47
contingent expenses	65 00
buildings and land	2,328 93
remitted to State Treasurer	41,929 90
Total	$149,340 28

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 213 JANUARY, 1923

TOBACCO WILDFIRE IN 1922

By P. J. ANDERSON and G. H. CHAPMAN

Wildfire continues to be the most destructive disease of tobacco in the Connecticut Valley. Experiments for the purpose of perfecting the old methods or finding new methods of checking the disease are in progress.

Results of the 1922 experiments and observations on control are summarized in this bulletin. The value of sterilization of seed, soil, sash and sideboards, spraying and dusting of plants in the bed and in the field, destruction of diseased areas in the beds, roguing of plants and removal of diseased leaves from the field are discussed and directions given for the application of these measures. This bulletin also discusses the overwintering of the wildfire bacteria and their dissemination during the summer.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

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Commission on Administration and Finance.

CONTENTS

BULLETIN No. 213.

DEPARTMENT OF BOTANY.

TOBACCO WILDFIRE IN 1922.[1]

BY P. J. ANDERSON AND G. H. CHAPMAN.

INTRODUCTION.

Wildfire in the Connecticut Valley.

Wildfire continues to be the most serious menace to the tobacco-growing industry of the Connecticut Valley. The season of 1922 was not less disastrous than that of 1921.

Beginning with the first recorded infection on May 7, fresh reports of infected seed-beds came in from every side with increasing frequency until it was estimated that 30 per cent of the beds of the valley contained some wildfire. No tobacco-growing town in Connecticut or Massachusetts escaped. Continuous rains and cloudy weather during the seed-bed period furnished ideal conditions for the spread of the disease and at the same time made it difficult to apply remedial measures. The same weather conditions continued throughout the setting period of June, and it was not surprising that the disease appeared in the fields almost as soon as the plants were established. It continued to spread there until, by the 4th of July, wildfire was raging in half the fields of the valley. The Broadleaf section was much more seriously affected than in 1921, while, on the other hand, many of the growers of other varieties escaped with less trouble than during the previous year. Growers were discouraged both by the wildfire and by the poor growth of the tobacco during this unfavorable weather, and some of them even plowed up their fields. But after the first week in July the weather cleared, there were no more long-continued rains, and such rains as occurred were followed by hot, clear weather. During the next three or four weeks wildfire spread hardly at all and the tobacco grew rapidly, covering the diseased leaves with healthy ones until many growers felt that the disease had passed. Rainstorms, however, became more frequent during the last few days of July and were accompanied by increased spread of disease throughout the topping period and, with but

[1] A report of co-operative work carried on by the Massachusetts Agricultural Experiment Station and the Tobacco Experiment Station of the Connecticut Agricultural Experiment Station. Published, with a different introduction, as Bulletin 2 of the latter station.

slight interruptions, until the crop was harvested. Many of the growers who had a slight foot-leaf infection profited by their experience of 1921 and did not wait for the tobacco to ripen, but cut it "on the green side" and in this way reduced the damage somewhat. It is probably no exaggeration to say that 90 per cent of the tobacco fields of the valley were more or less affected. Some fields were so badly "fired" that not a clean plant could be found, and the price received for the crop will be but a fraction of the cost of growing.

Wildfire in Other Sections.

During the summer one of the writers had occasion to visit the tobacco regions of New Hampshire and Vermont, where conditions were found to be very similar to those which prevailed in Massachusetts.

A serious outbreak occurred in Wisconsin (Pl. Dis. Bul. 6: 40, 139), from which State the disease had not been reported previously from farms. It was also reported for the first time from New York and Georgia (Pl. Dis. Bul. 6: 62, 63). It occurred with more or less severity in Pennsylvania, Maryland, Kentucky (Pl. Dis. Bul. 6:21) and Ohio. It is rather surprising to find that in North Carolina and Virginia, in which States the disease was first found and where it was very destructive five years ago, there has been no damage from wildfire during 1922. Under date of August 19, Dr. F. D. Fromme, plant pathologist of the Virginia Agricultural Experiment Station, wrote: "We have yet to see a case of wildfire in the 1922 crop in Virginia. We have inspected well over 100 fields in counties where it has occurred in the past year. Plant beds were equally free from it this year." Under date of August 21, Dr. F. A. Wolf, plant pathologist of the North Carolina Agricultural Experiment Station, wrote: " I have not received this season a single authentic specimen of tobacco wildfire from this State."

Previous to this year wildfire was not known to occur outside the United States. It has now been reported from South Africa (2:366–368).[1]

Progress in Investigations.

Investigations with the object of developing some method or methods of preventing loss from wildfire, begun in 1921, were continued by the writers in 1922.[2] Although such methods have not been perfected as yet, nevertheless some improvements have been made on the methods previously recommended, and by another season of work we have been able to confirm more fully some measures which were recommended, while others have been found to be of less importance. Some further studies have

[1] The first number in the parenthesis refers to the bibliography on page 27 of this bulletin, and the numbers after the colon refer to pages of these publications.

[2] Results of the investigations of 1921 are recorded in Bulletin 203 of the Massachusetts Agricultural Experiment Station. Subsequent to the publication of that bulletin, Chapman has been located at the Connecticut Tobacco Substation in Windsor, but the work has been continued in co-operation between that station and the Massachusetts Agricultural Experiment Station. Valuable contributions to our knowledge of wildfire have been made by Clinton and McCormick in Connecticut, and published during the last year as Bulletin 239 of the Connecticut Agricultural Experiment Station. This bulletin and a number of other important publications on wildfire which have appeared during the last year are freely quoted and referred to here in order that the grower who reads the present bulletin may have the advantage of all that has been learned concerning this problem.

been made in regard to the life history of the causal organism, especially with reference to overwintering and dissemination. The results of the life history and control work of 1922 are briefly presented in the present bulletin.

Valuable assistance in the work has been rendered by Prof. A. V. Osmun of the Massachusetts Experiment Station and Mr. C. M. Slagg of the United States Department of Agriculture. Tobacco growers in both States, too numerous to mention here by name, have co-operated heartily with the writers in the work described in the following pages.

LIFE HISTORY STUDIES.

Overwintering of the Bacteria.

As a basis for control measures, probably no problem in regard to life history of the causal organism[1] is more important than determination of the method or methods by which the bacteria survive the winter and thus serve as starting points for wildfire of the next year. Certain experiments with the object of solving this problem were conducted during the winter of 1921–22, and though some of the results are not conclusive progress to date is reported at this time. Other experiments with the same object are now in progress, and it is hoped that they will be more satisfactory.

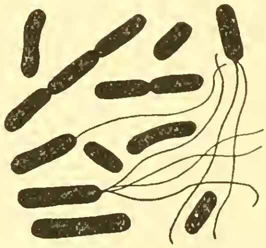

Fig. 1. — A group of the bacteria which cause wildfire. Magnified 5,000 times.

Effect of Freezing the Bacteria.

In studying the problem of overwintering, the first point to be determined is the effect which freezing has on the organisms. If they are not able to withstand the exposure of a New England winter, then the measures of control will be quite different from those which should be tried if they are resistant to cold. Pure cultures of *Bacterium tabacum* on agar were placed out of doors at various times during the winter of 1921–22, some of them being frozen solid for months; but in every case when they were brought back

[1] Wildfire is produced by the parasitic growth of enormous numbers of bacteria (*Bacterium tabacum* Wolf and Foster) in the leaves. Since various investigators who have published concerning the organism do not agree as to some of the morphological characters, Anderson during the past season has made and studied permanent slides on which the bacteria have been stained by (1) the Duckwell modification of the Pitfield method, (2) the Shunk method (Journ. Bact. 5: 181, 1920), and (3) to a less extent by other methods. The organisms are short, cylindrical rods with rounded ends and usually straight sides, but not infrequently individuals are found which are slightly curved or somewhat dumb-bell shaped. Frequently two or three of them remain end to end in a chain on the slide. Those in chains are shorter, indicating immaturity. Only those which were free from each other were used in measuring. The average size of fifty taken from five slides stained in different ways was 2.3x.8 μ. The longest one measured was 3.8 μ and the shortest 1.4 μ. Attached to one end there are one to four flagella several times as long as the body of the bacterium. The bacteria in text, Fig. 1, were drawn from a slide stained by the modified Pitfield method.

into the laboratory and transferred to other media they grew normally. The result was about what one would expect when it is remembered that few species of bacteria are killed by freezing. It is certain from data presented below that freezing does not kill them while in the leaf in the tobacco barn.

On the Seed.

It has been suspected by most workers who have investigated this disease that the bacteria may survive the winter on or with the seed, and that early infections in sterilized beds originate in this way. Although this would seem possible, there is as yet no experimental evidence to prove that such is the case in the Connecticut Valley. In Virginia, Fromme and Wingard (3) find conclusive evidence that the organism of blackfire of tobacco (*Bacterium angulatum*) overwinters in this way. Their evidence for the wildfire organism, however, is not so convincing. A number of experiments were undertaken by the writers for the purpose of determining the possibility of overwintering in this way. In the interest of brevity these experiments need not be given in detail, but the results may be summarized: —

1. All attempts to isolate the organism directly from suspected seed have failed.
2. Suspected seed has been planted and no wildfire has appeared on the seedlings where other sources of infection have been eliminated.
3. Seed inoculated by soaking in a pure culture of the bacteria and kept in a dry room all winter produced only clean plants in the spring.
4. In another experiment seed was artificially inoculated after it had been sterilized and the bacteria killed by heat. The seed remained wet from the culture for two weeks. In the spring it was sprinkled on healthy leaves and wildfire resulted, but the conditions are not the same as where seed is kept in a dry room.

All the evidence in these experiments was negative and has only the weight of such. The possibility is not precluded that there may be conditions under which the bacteria may winter directly on the seed coat.

There is no evidence that in nature a lesion may come in direct contact with the seed. No one has ever reported seeing a lesion on the seed. It is a well-known fact, however, that lesions do occur on the calyx of the flower and on the seed pod. During 1921 in Connecticut and during the late summer of 1922 in Massachusetts, pod lesions were found on plants being kept for seed. Similar lesions were also produced by artificial inoculation. In threshing out the seed small broken bits of the pods remain with the seed as chaff, and no amount of sifting and cleaning will remove every particle of chaff. If the bacteria overwinter in the seed, it is probably not directly on the seed but in these fragments of pods, etc., which are with the seed. Since it is known that they survive the winter in leaf lesions, there could hardly be any doubt that they could live over in similar lesions on the pods. Fromme and Wingard (3:20) present experimental evidence showing that the percentage of wildfire is increased by top-dressing the seed-bed with chaff from infected pods of the previous year. It seems improbable, however, that any considerable proportion of the spring infection in the Connecticut Valley beds starts from the seed, because (1) growers now know the disease well enough so that few of them would save seed from infected plants; (2) many of the growers during the last season used old seed (grown previous to 1920) and yet they did not escape infection; (3) those who sterilized the seed were apparently no more successful in eliminating the disease from the beds than those who did not;[1] (4) even those who advocate most strongly the sterilization of seed do not present convincing data to prove that the disease organism is carried on the seed.

In the Soil.

From the plant the bacteria may get into the soil in two ways: (1) they may be washed from the plant by the rain during the growing season; and (2) when the leaves or other infected parts are turned into the soil or left to rot on the soil, the bacteria probably remain alive for a long time. It is important that we should know how long they remain alive there and capable of infection and whether they may survive the winter in this habitat.

Experiment 1. — In order to see whether the organisms could be carried from one crop to the next through the medium of naturally infested soil, such soil was taken from three beds of diseased plants at different times during the summer of 1921 and seeded with sterilized seed. The plants grown in this soil did not become infected. On the other hand, in one of the greenhouse beds which had grown a number of diseased crops, sterile seed was planted in the spring of 1922 and the seedlings became diseased before the plants were an inch high.

Experiment 2. — In this experiment one pot of soil was inoculated by spraying a suspension of bacteria over it, while another pot had an equal amount of water sprayed on it. Both were seeded shortly after sprinkling, and wildfire developed in the inoculated pot but not in the check.

During some control experiments in Whately, it was observed that even when all diseased leaves were removed from the plants, others became infected after rains and almost always on the tips which were beaten down into the soil. It appeared as though the bacteria had been washed from the diseased leaves into the soil and then splashed from the soil to other leaves.

In two fields in Hadley and North Hadley which were under constant observation by one of the writers during 1922, the plants became so badly diseased during June that all were pulled and carted from the fields. Both fields were set later with healthy plants, but in both cases there was a very heavy reinfection before the new plants were half grown. The second infection must have come by way of the soil.

Clinton and McCormick (2:404) buried wildfire leaves under healthy plants, and by this means the infection was increased to 63 per cent as compared with 13 per cent on adjacent plants not so treated.

[1] Records were kept on the beds of 11 growers in Massachusetts who treated their seed with mercuric chloride. Wildfire afterward appeared in 5, while the other 6 had no wildfire in the beds.

The above data furnish very strong evidence that the pathogen may be carried from one plant to another or from one crop to another by means of the soil. The failure to get infection in some of the experiments by planting in infested soil shows, however, that infection will not always result necessarily because the soil was infested.

None of the experiments just quoted furnishes evidence of the length of time during which the bacteria may remain alive in the soil or indicates whether they will live through the winter in this habitat. The following experiments and observations throw some light on the latter point: —

Experiment 3. — On July 1, 1921, Erlenmeyer flasks of soil were sterilized and later inoculated with the bacteria. Part were plugged only with cotton, others were paraffined to prevent drying out. At various times during the winter, soil was taken from these flasks and plated out. Then, when bacteria developed about the particles of earth, they were shaken in a suspension of water and atomized on healthy plants. In the flasks which did not have paraffined plugs, the soil became very dry, while in the others it remained muddy. Heavy infection resulted when inoculations were made March 10 and others on March 20, 1922, from the dry flasks, but none from the tightly closed wet flasks. These flasks were kept in the laboratory and were not frozen. In this case the bacteria were still able to produce infection after eight months.

In two instances in Connecticut, wildfire was found starting in the edge of the beds in soil which had been outside the pans when the remainder of the beds were steamed. In both cases wildfire was present in the beds in 1921. The fact that the planks were new and the sash had been sterilized with formaldehyde eliminated these as the source of infection.

In a number of cases, in both States, it was found that those parts of the field which were diseased in 1921 showed the heaviest infection in 1922.

On the other hand, fields have been observed which were badly diseased in 1921 and on which tobacco was free from wildfire in 1922.

On one of the fields at the Connecticut Experiment Station the 1921 crop which was badly infected with wildfire was cut late in September and left lying on the ground over winter with a view to getting data on the overwintering under natural conditions. In this case both leaves and stalks were left to weather. In 1922 this field was planted with Havana and Broadleaf wildfire-free seedlings, the stalks and leaves of the 1921 crop having been disked and plowed under two weeks prior to setting. Throughout the season close examinations were made by Slagg and Chapman for wildfire in this field. Wildfire was not found on this particular field during the growing season, but at harvest an occasional wildfire spot was found, yet nothing to what should have developed if any considerable amount of direct infection occurred as a result of the refuse being left on the field. A careful estimate of the wildfire plants on this plot, made at harvesting, showed that infected plants were not more than one-half of 1 per cent of the total number, and on all of these the infection was light. This slight infection may have come from plants in the wildfire experimental field, since all the station plots — except for the experimental field — showed about this same percentage of infection late in the season.

Clinton and McCormick (2: 376, 419) succeeded in one experiment in infecting tobacco plants in the greenhouse by direct application of over-wintered soil which had been exposed to infection the previous year. Wolf and Moss (4: 30) in North Carolina and Fromme and Wingard (3: 24) in Virginia present considerable evidence that in the South the organism winters in the soil, but we cannot accept this as conclusive proof of the same condition in New England.

Altogether the weight of laboratory data and field observations indicates that *Bacterium tabacum* is able in some cases to survive the winter in the soil and start new infection from this source in the spring. On the other hand, it is apparently possible under some conditions to raise a clean crop of tobacco on a field that has borne diseased crops during preceding years. The evidence as to soil wintering is, however, not so convincing as it should be, and further experiments are now under way which it is hoped will remedy the deficiency.

In Cured Leaves.

That the bacteria do not die when the diseased leaves are cured in the tobacco barn has been demonstrated in a number of our experiments.

Experiment 4. — On March 5, 1922, diseased cured leaves were taken from the Hampshire County warehouse just before they were ready to go into the case. They had been in the tobacco barn under normal conditions all winter. They were ground to a powder in a mortar and the powder was sprinkled on wet plants in the greenhouse. After two weeks the plants developed typical lesions of wildfire. Other leaves were ground and the experiment was repeated with the same result on March 28. On March 8 some diseased leaves were received from Mr. H. C. Wells of Deerfield. Some of them were ground and used for inoculation just as the above. Dilution plates were made from the others and the organism thus isolated used for making inoculations. Wildfire developed on the plants inoculated in both ways.

Experiment 5. — At Windsor, several times during the winter, wildfire spots from leaves kept in the station shed were brought to the laboratory and the wildfire organism isolated in pure culture. Cultures of wildfire bacteria were obtained from these leaves until the middle of March in this way, and no doubt living bacteria could have been found later than this.

These experiments were conclusive and there can now be no doubt that the wildfire organism can overwinter in cured leaves. It might get back from the cured leaves to the next year's crop in any one of a number of ways: (1) Refuse containing lesions from the shed may be thrown back to the land. (2) Sash and plank are sometimes stored in the tobacco sheds. Bits of broken diseased leaves could easily be carried out on such sash and plank and serve to start infection in the seed-bed. (3) While drawing the tobacco to the warehouse across or near the fields, parts of the diseased leaves might be scattered on the land.

Clinton and McCormick (2: 417) isolated *Bacterium tabacum* from tobacco leaves which had been dried and kept in the herbarium for periods ranging from one hundred and ninety-eight to two hundred and ninety-eight days. They were unable, however, to secure the bacteria from other leaves which had been kept for two years.

In Leaves which have been left in the Field.

Sometimes leaves when too badly diseased are picked off and thrown on the ground. At other times the whole diseased plant may be left. The suckers which grow from the old stubs after a diseased crop has been cut are usually infected. These are left on the field all winter. If the bacteria live over in these parts, they might easily start infection the following year. Being subjected to more frequent freezing and thawing and other changes of weather, it is possible that they might not survive in these leaves as they do in cured leaves in the tobacco sheds. We have very little data bearing on this point.

Experiment 6. — On April 24, 1922, diseased leaves, which had been cut down in the fall and left in the field all winter, were collected from plants at Windsor. These leaves were ground to a powder in a mortar, some of the powder was immediately applied to punctured leaves in the greenhouse at Amherst, and some of it soaked in water and the wet material applied after twenty-four hours to other plants. No infection resulted.

Similar tests were made with the same material by Chapman and Slagg, but with negative results. This negative evidence should not be considered conclusive. Further experiments are in progress.

Clinton and McCormick (2: 376, 419) succeeded in one case in infecting tobacco plants in the greenhouse with tobacco refuse which was wintered out of doors.

Occurrence of Lesions on Stalks.

Wildfire lesions have been reported previously as occurring only on the leaves and occasionally on the pods. During the inspection of a field of tobacco at South Amherst, some lesions which were suspected of being wildfire were found on the stalks. On further examination it was found that the lesions were not uncommon, but that they were present on a large part of the stalks in this field. Probably they had escaped previous notice because they are inconspicuous and somewhat different in appearance from the lesions on the leaves. They are commonly one-eighth to one-fourth inch in diameter, white, or, at most, light brown and sunken. The halo is not distinct on most of them, but can be seen about some. A number of them were brought to the laboratory and the typical bacteria isolated from them. Inoculation on leaves with these bacteria produced wildfire spots. In this same field and in various others examined through the summer, it was also observed that lesions were common on the "ears" or clasping bases of the leaves. When tobacco is stripped, these bases remain mostly on the stalk. Clinton and McCormick (2: 416) inoculated stalks and produced elongated blackened lesions. The occurrence of lesions on stalks and attached leaf bases may be important in answering the question as to whether land may become infested by throwing tobacco stalks on it. Since the organism overwinters in the leaves, there is no reason why it should not also remain alive in the stalk.

Occurrence of Lesions on Midribs.

In the process of "stemming" tobacco, the midribs are stripped from the leaf and are sold as fertilizer (incorrectly called tobacco stems). The question has frequently been raised as to whether the land may become infested by the use of "stems" from diseased tobacco. Observations as to the occurence of lesions on midribs were made at various times in fields during the summer. Frequently lesions were found running along both sides and encroaching on the midrib and often extending directly across the midrib. When the leaf was stripped from the midrib, parts of the lesion remained with the "stem." *Bacterium tabacum* was isolated directly from such denuded stems. This does not prove that the disease may be carried back to the land by using stems, since it has still to be demonstrated that the bacteria can survive the sweating process, but there can be no doubt that they occur in the midribs and may survive the winter thus in the tobacco shed. Clinton and McCormick (2: 416) produced lesions similar to those described above by inoculating the midribs with pure cultures of the bacteria.

Relation of the Condition of the Plant to Infection.

No set of experiments has been planned to determine the relation of the growth and vigor of the plant to susceptibility, but incidental to other experiments a number of observations have been made which indicate that a rapidly growing plant is much more susceptible than one which is growing slowly. During the fall of 1921 two beds were planted in the greenhouse at Amherst, — one on very poor soil and one on soil rich in rotted compost. Both were inoculated at various times and the rapidly growing plants of the fertile bed became infected, but all inoculations failed in the other bed until late in the spring, when the plants suddenly began to grow rapidly. In the course of some experiments at the Massachusetts Station during the summer of 1922 numerous unsuccessful attempts were made to inoculate a bed of very slow-growing plants which had received no fertilizer. During the same time other rapidly growing beds in the greenhouse were very readily infected. These experiments are not accurate, but certainly give some strong indications. Also the fact that infection is difficult to secure during the winter months points to the same conclusion. The relation of fertilizers to infection can probably be interpreted by their influence in producing a rapid, succulent growth or the reverse. Other investigators of the disease have made similar observations. Clinton and McCormick (2: 390) state that "the use of any fertilizer that favors rapid growth is more likely to help infection . . . than where the fertilization is such that slower or less satisfactory growth takes place." Fromme and Wingard (3: 27) express essentially the same opinion.

Dissemination.

No experiments directly dealing with dissemination were undertaken during the season of 1922, but observations throughout the year confirm the conclusions of 1921 in most respects. There is one notable exception, — the experiments and observations in 1921 led us to believe that all field infection originated from plants which were diseased when taken from the beds. The majority of the field infections, and the worst ones which we have seen in 1922, did come from that source and could be traced without any question to the seed-bed. On the other hand, a number of cases have come to the writers' attention where the beds were free from disease (if it is possible at all to tell when they are free), but disease developed in the fields set from these same beds. A few cases may be mentioned: —

1. Anderson inspected the beds of a certain Sunderland grower at intervals of three or four days throughout the season and is positive that they were free from disease. Yet parts of the fields set from these beds were very badly diseased.
2. Tobacco fields owned by a grower in South Deerfield, but located near Brattleboro, Vt., became badly diseased, and were visited by A. V. Osmun and Anderson in June. Most of these fields were set from beds near the fields, but some plants were brought from the beds in South Deerfield. A most searching examination of the beds at both places failed to reveal a single diseased plant.
3. A field of tobacco on a farm in Whately was isolated from all other tobacco fields and surrounded on all sides by woods. Plants were taken from the beds on the same farm. During the spring these beds were repeatedly inspected by C. M. Slagg, a wildfire expert, but he failed to find any infection. Yet wildfire became fairly prevalent in the isolated field.
4. The seed-beds of a grower in North Hadley were frequently inspected by Anderson during the spring, and not a trace of wildfire could be found at any time. During August some diseased plants were found in the middle of the grower's field.
5. Wildfire occurred in a field of the Massachusetts Experiment Station farm which was not being used for wildfire work, but not a trace of it had been seen in the beds at the experiment station where the plants were raised.
6. A certain Windsor grower kept his seed-beds covered at all times with copper lime dust, and frequent inspections by Chapman and Slagg showed no infection. He planted two fields, about 3 miles apart, from these beds. One of the fields developed a heavy infection during the growing season; on the other, only a trace of wildfire was found.

Many similar cases were reported by growers, but were not checked by the personal observations of the writers. The evidence is conclusive that not all field infection comes from the seed-bed. We are now confronted with the problem of determining how such infections did start. Rain could not have brought them from other fields because they were too far removed. There is some probability that in the Sunderland field the bacteria were in the soil over winter, since the worst infection occurred in the same place as last year. In the other cases, however, either no tobacco had been planted during the previous year on these fields or no wildfire had been observed there during 1921. Apparently there is some long distance disseminator which we have not yet found. Those that suggest themselves are (1) workmen, (2) insects, and (3) wind. Since many isolated infections were discovered within a week or two after the exceptional windstorm of June 12–13, it is possible that the organisms may have been spread with the dust and sand which were blown in great clouds over the valley at that time. It has been shown above in this report that dry, infested soil dusted over healthy plants may produce infection.

All observations of the summer confirm our previous conclusion that the most important short distance disseminator of the disease in the field is the rain, especially when accompanied by wind. It should be noted here, however, that not every rainstorm is followed by a new outbreak of wildfire. It was frequently remarked, especially during July, that heavy short rains quickly followed by drying weather resulted in very little spread of the disease. The ideal conditions for spread are (1) long-continued rains, (2) rains followed by cloudy weather during which the leaves do not become dry, or (3) periods during which the rains follow each other closely. During June of 1922 we had a long-continued combination of all three of the above conditions, which resulted in the worst spread of wildfire which we have ever seen.

CONTROL MEASURES.

Sterilization of Seed.

Seed sterilization has been recommended by the writers because it was thought possible that the bacteria might be carried on or with the seed. Fromme and Wingard (3: 20) of the Virginia Experiment Station, in fact, are of the opinion that a large part of the infection is started from the seed. Although there is no conclusive evidence in the Connecticut Valley or elsewhere that such is the case, nevertheless the practice was recommended as a precautionary measure. In 1921 formaldehyde was recommended as the disinfectant (1: 75), but this year mercuric chloride was recommended because it was found to be just as efficient and was less likely to cause injury to the seed; therefore the following directions for treating tobacco seed were sent out to tobacco growers before planting time.

Purchase corrosive sublimate tablets at any drug store. Dissolve one tablet in a pint of water to make a 1/1000 solution. Use a glass jar. Place seed in a cheesecloth bag and soak in the solution for exactly fifteen minutes. Poke or stir occasionally with a stick to insure thorough wetting of all the seed. Remove bag of seed and wash thoroughly in water. Spread out seed in a warm room to dry. Store seed where it will not become contaminated. Germination of the seed will not be affected if directions are followed carefully.

Many of the growers in 1922 used the corrosive sublimate treatment for sterilizing their tobacco seed; and at the Windsor laboratory one hundred and twenty lots of seed were sterilized by this method, and the germination before and after sterilization was tested. In no instance in the laboratory tests was there any injury from such seed treatment.

Some of the growers, however, reported that they injured the seed by the corrosive sublimate treatment. Some said that germination was retarded, others that the percentage of germination was lowered; and others that the seed would not germinate at all. It was at first thought that the failure was due to faulty technique, but laboratory tests showed that even a treatment of thirty minutes was not harmful, and some of the growers omitted the washing of the seed after sterilizing without any bad effect. Some reported lack of germination in seed which was sterilized at the tobacco substation by Chapman. It was certain, then, that the injury could not be attributed to faulty technique in all cases. Inquiry among the growers as to the method by which they sprout the seed revealed one difference between their method and that used at the stations, viz., the custom which many growers have of cracking or sprouting the seed in moist cocoanut fiber or apple punk or between sods for a few days before planting. The seed is kept in a warm room of 70 to 90° F. and from time to time sufficient water is added to keep the fiber or other material slightly moist. It was thought that possibly the fiber might have something to do with the lack of germination and some of the seed was taken to the laboratory for test, using both unsterilized and sterilized seed of different lots. It was found that the unsterilized seed sprouted in the fiber and that the sterilized seed did not show any signs of sprouting even after ten days. Other growers brought in samples of seed which they themselves had sterilized and which had failed to sprout in fiber, and these lots were tested also. Chapman tried varying the conditions under which the seed was kept during the sprouting period and found that under the conditions ordinarily used it was almost impossible to sprout the sterilized seed, although the same seed in Petri dishes would germinate satisfactorily. It was found finally that in order to germinate sterilized seed, whether in punk or fiber, the pans should be kept at a lower temperature and also that the moisture content of fiber or punk must be considerably higher than usual. By close attention to these factors it was possible to sprout the different lots of sterilized seed in either punk or fiber almost as well as before sterilization.

Lack of germination of sterilized seed under usual conditions in punk or fiber appears to be due to the fact that the seed coat is hardened by the washing and drying and there is a much slower softening of the seed coat than is the case with the unsterilized seed. This was tested in the following way: —

Experiment 7. — Of two lots of seed, one was sterilized for fifteen minutes with a solution of 1/1000 corrosive sublimate, and the other treated for fifteen minutes in pure water without any chemical added. Both lots were taken from the jars and washed and dried in the usual manner. It was found to our surprise that both lots reacted the same; i.e., when placed in punk or fiber under normal conditions, the germination was greatly delayed or lacking. This experiment showed that lack of germination was not due to the corrosive sublimate treatment, but to another cause, probably the hardening of the seed coat by the washing process or possibly by the rapid drying.

The age of the seed or storage conditions may possibly play a rôle also, as in many cases growers had no difficulty with their seed. A few cases were brought to our attention where the injury was undoubtedly due to incorrect procedure in the corrosive sublimate method.

Data collected from growers who sterilized their seed during 1922 are not conclusive as to the value of the treatment for preventing wildfire.

As a result of our experience this past year, we are of the opinion that in the Connecticut Valley, seed is, at most, a minor source of infection. Nevertheless, this is a possibility which should not be lightly overlooked, and growers should not save seed from plants which show wildfire infection. If this is found necessary, however, we believe the seed should be treated with the corrosive sublimate. To avoid the difficulties discussed above, the beds should be sown with the dry seed. We do not know how long the bacteria will remain on the seed, but it is unlikely that there would be any alive on seed two or three years old. By the use of old seed the chance of infection from this source would be eliminated.

Sterilization of Soil in the Seed-bed.

Sterilization of the seed-bed soil with either steam or formaldehyde was recommended by the writers (1: 75) because it was thought possible that the organism could live from one season to the next in the soil. Considerable additional evidence that this is one of the ways in which it may pass the winter has been obtained during 1922 and presented in a previous part of this report. It is a common practice for growers to sterilize their beds to kill weed seeds, prevent root rot and for other reasons; and many beds were sterilized before the 1922 seed was sowed, a few in the fall and more in the spring. Careful records were taken on fourteen beds in Massachusetts which had been sterilized this year. Wildfire occurred in seven of them and the others remained free. No conclusion can be drawn from these data except that soil sterilization alone cannot be depended on to give a clean seed-bed. It is unquestionable that sterilization of soil by either steam or formaldehyde if properly done will kill all the wildfire bacteria in the soil treated, but it may not be so easy to eliminate the possibility of getting it contaminated again from infested soil in the walks, surrounding areas, tools, etc. These chances are perhaps greater where soil is sterilized in the autumn. Most growers use steam and consider it cheaper. If steam is used, it should be applied for thirty minutes at 100 pounds pressure. Those who do not have boilers which will produce so high a pressure may determine the proper length of exposure by burying a small potato 4 or 5 inches below the surface of the soil under the pan and applying the steam until it is cooked through. Only one of the fourteen mentioned above used formaldehyde. Formaldehyde at a dilution of 1/50 in water is applied at the rate of one-half to three-quarters gallon to the square foot of surface. Some preferred to change the location of the beds rather than sterilize the soil. In Massachusetts accurate records were kept on eight beds, the location of which had been changed to places where no tobacco was planted last year. Four of them had wildfire this year and four did not. The practice of sterilizing the beds should be continued not only to destroy wildfire bacteria but also to kill other disease organisms and weed seeds.

Sterilization of Sash and Plank.

The writers (1: 76) in 1921 recommended that old sash and plank be drenched with a $1/50$ formaldehyde solution, and this was practiced by a number of growers. Some painted the sash and used new plank.

Data as to the benefits from this practice during 1922 are not very conclusive because in most cases other sources of introduction were not eliminated, but in a few cases under the writers' constant observation clean plants were raised in 1922 under the same sash and with the same sideboards (after sterilizing both) which had been used for badly diseased beds in 1921. Danger of infection from contaminated sash is well illustrated by the following experience of a Connecticut grower: His seed-beds in 1921 were so heavily infected in June with wildfire that the plants were destroyed. The sideboards were destroyed, the beds plowed up, and the sash stored over winter in a tobacco barn. The grower in 1922 decided to take no chances of a wildfire infection and contracted with a farmer who did not raise tobacco to grow sufficient plants for his use. The farm on which the plants were grown was remote from any tobacco fields or beds, new land was plowed and fitted, and old seed in which there was no possibility of contamination was used. It might be supposed that these precautions would insure freedom from the trouble; but as the farmer growing the plants had no sash, the sash used on the beds in 1921 were taken from the first farm and used on the beds. They were not sterilized, and shortly after the plants were up a very heavy infection occurred on all the beds on which the sash were used. While the proof is not absolutely conclusive, the inference is justified that the sash carried the bacteria. Unfortunately no beds without sash were grown in this particular instance, but it might be said that the possibility of contamination from other sources was slight indeed.

The following laboratory experiment was made with the object of determining how long the bacteria would remain alive on a piece of dry wood such as a side plank or sash: —

Experiment 8. — Small blocks of pine wood were sterilized and then soaked for eight days in a pure culture of *Bacterium tabacum* in bouillon. Then they were removed to dry, sterile tubes, where they quickly became dry and were kept so for further tests. The experiment was begun July 1, 1921, and the blocks were kept in the laboratory. At various intervals the blocks were tested for live bacteria by dropping one in sterile bouillon. They were still alive on September 10, but were dead on December 3. Sometime between these dates the last of them died. Apparently, then, they are able to live three months or more on dry wood.

In this laboratory experiment, however, the conditions are not the same as they would be in nature: (1) The wood is dried out more rapidly by the laboratory air than by the out-of-door air where they are stored. Sash are usually stored in a tobacco shed or barn, while the planks may even be left out in the weather. The conditions in the shed are more favorable than the laboratory for the survival of the pathogen. (2) If sash are kept in the tobacco shed, it is possible for diseased parts of the hanging crop to become lodged on them. (3) If the plank are kept out of doors, the moisture conditions would be about the same as for soil. In fact, the bacteria might be alive in soil which remains attached to the plank. Since we know that the bacteria can remain alive in the leaves and in the soil over winter, there would seem to be no reason why the sash or plank would not be a source of danger. Wolf and Moss (4: 32) and Fromme and Wingard (3: 22) have presented evidence to show that the germs may be introduced into new beds by the use of old cloth covers which were previously used on infested beds. If such cloth covers or the tent covers used in previous years over wildfire crops are used, they should either be boiled thoroughly in water or soaked in formaldehyde like the sash and planks.

Spraying and Dusting Seed-beds.

Results of the first experiment on the control of tobacco wildfire by spraying or dusting the seed-bed have been published in Bulletin 203 of the Massachusetts Agricultural Experiment Station. Subsequent to the publication of that bulletin the experiment has been repeated at Amherst four times, using a greenhouse bed 4 x 16 feet for each experiment. The plants were pulled and counted when they were large enough for setting in the field, and then the bed was seeded immediately for the next experiment. The soil was not sterilized between experiments. The greenhouse bed was used in preference to an out-of-door bed because in this way a longer season could be secured and the experiment repeated more times.

Some of the fungicides used in the first experiment were omitted in later experiments because they were found to cause injury to the plants, viz., sulfur dust, lime-sulfur and the Pickering Bordeaux. NuRexo was used in the second experiment but omitted in the later ones, not because it failed to give control, but because it was thought best to confine the tests to one commercial copper spray. The copper-lime dust for the first experiment was furnished by the Riches, Piver & Co.; the dust for the later experiments by the Niagara Sprayer Company; the Pyrox was furnished for all experiments by the Bowker Insecticide Company. In order that all the data may be compared at a glance, the tables of results are first assembled and presented here all together and then followed by the general discussion.

Tests of Fungicides for the Control of Wildfire.

Description of Test.	Fungicides.	Total Number of Plants.	Diseased Plants. Number.	Diseased Plants. Per Cent.	Number of Lesions per 100 Plants.
Experiment 9: June 6 to July 26, 1921. Cloth bed, out of doors. Two applications at intervals of one week. (Bulletin 203.)	Bordeaux 4-4-50 (2 plots)	473	6	1.25	2.5
	Copper-lime dust 20-80 (2 plots)	534	3	.55	.5
	NuRexo (2 plots)	600	3	.48	.5
	Pyrox 10-50 (2 plots)	570	23	4.1	6.5
	No fungicide (4 plots)	1,079	527	48.25	178.2
Experiment 10: Oct. 10 to Dec. 10, 1921. Greenhouse. Three applications at intervals of about a week.	Bordeaux 4-4-50	848	0	0	0
	Copper-lime dust 20-80	771	3	.38	1.2
	NuRexo	747	6	.8	1.2
	Pyrox 12-40	863	5	.58	1.1
	No fungicide	1,092	221	20.2	37.5
Experiment 11: March 17 to May 10, 1922. Greenhouse. Three applications at intervals of over a week. Some infection started before first application.	Bordeaux 4-4-50	1,637	3	.2	.3
	Copper-lime dust 20-80	1,449	152[1]	10.2	30.1
	Pyrox 12-50	1,375	140[1]	10.0	25.8
	No fungicide	1,714	1,322	77.0	484.0
Experiment 12: May 17 to June 28, 1922. Greenhouse. Five applications at intervals of three or four days.	Bordeaux 4-4-50	1,176	2	.1	.1
	Copper-lime dust 20-80	821	0	0	0
	Pyrox 12-50	1,005	3	.3	.5
	No fungicide	883	499	57.0	208.0
Experiment 13: July 14 to Aug. 26, 1922. Greenhouse. Five applications at intervals of three to five days.	Bordeaux 4-4-50	1,205	12	1.0	1.2
	Copper-lime dust 20-80	1,056	3	.3	.4
	Pyrox 12-50	1,276	12	1.0	1.2
	No fungicide	938	860	92.0	487.0

[1] The high percentage of infection in this experiment is explained by the long intervals between applications and the fact that the bed was watered every day and inoculated twice a week.

Experiment 14. — In similar experiments at Windsor the beds were on soil which had grown a heavily infected crop of tobacco in 1921. The beds were not artificially inoculated as in the preceding experiments. The fungicides used were Sanders Dust No. 1, Niagara 20-80 copper-lime dust, Dosch 15-85 copper-lime dust, orchard brand Bordeaux lead and Bordeaux zinc. Seven applications were made at intervals of three to five days. A natural infection developed on the untreated plot and in one corner of a plot next to it. No other wildfire developed on the treated plots.

Conclusions from the Experiments and Practical Applications.

Frequency of Application. — The writers recommended in 1921 (1: 81) that the fungicide be applied once a week. Later experiments indicate, however, that this is not sufficient under the following conditions: —

1. When the plants are watered very frequently. On some soils it is necessary to water the beds heavily every day. Most of the fungicide is washed off before the end of a week. This factor was tested in Experi-

ment 11, where the plants were watered and inoculated every day or two. The percentage of infection was fairly high on the Pyrox plot and the dust plot. (The plants in the Bordeaux plot of this experiment were very small and in poor condition on account of accidental burning by cyanide gas which was used to fumigate the house. The low percentage of infection on this plot is not significant.) In the next experiment (Experiment 12) the plants were watered and inoculated less frequently and the fungicide was applied oftener. The infection was thus reduced again to less than 1 per cent.

2. When the beds are exposed to frequent rains. The first rains wash off the fungicide and later rains spread the bacteria. Even when the beds are covered during rains there is usually considerable drip through the sash between the glass.

3. When the plants are growing very rapidly, as they usually are just before setting begins. New leaves are produced so rapidly that many of them will be left unprotected for several days if the application is made only once a week.

No definite interval of time between applications can be regarded as safe. There are too many influencing factors. The only safe rule is to *keep all leaves covered at all times with the germicide.* During the very rainy season of 1922 no less than eight or ten applications would have been necessary. Growers have also found it a good practice to dust or spray the beds each time they are pulled over for setting.

Amount of Material to be applied. — In applying the dust or spray the only safe rule for judging whether enough has been applied is to note whether all leaves are covered. The amount of material required to produce a thorough covering will vary somewhat with the type of machine used and the stage of growth of the plant. In the experiments recorded above, in which a small rotary hand duster was used, it was found that no less than a pound of dust for each application was required to cover a square rod of plants when they were of a size suitable for setting. With the compressed air sprayer which was used, $1\frac{1}{2}$ to 2 gallons of spray material were found to be sufficient to cover the same area.

Relative Cost of Spraying and Dusting. — At the local stores in Amherst and Windsor lime cost $4.90 per barrel of 280 pounds, or, since a little more if in smaller quantities, about 2 cents a pound, copper sulfate 11 cents a pound, Pyrox 20 cents a pound and copper-lime dust 10 cents a pound. Using the amounts per square rod which are indicated above, the cost of materials for eight applications would be as follows: —

Bordeaux 4–4–50	12 cents per square rod.
Pyrox 12–50	58 cents per square rod.
Copper-lime dust	80 cents per square rod.

Thus the cost of materials of a commercial fungicide such as Pyrox is nearly five times as great as that of the home-made Bordeaux, while the cost of the dust is nearly seven times as much. A good compressed air sprayer can be secured on the local market for $7 to $10.50, while a suitable dust blower costs $12.50 to $18.50. The advantage which the Bordeaux mixture has in cheapness, however, is counterbalanced by the increased time and labor involved in its preparation. The copper-lime dust is immediately ready for application when received, and the Pyrox or NuRexo has only to be dissolved in water.

Dust v. Liquid Sprays. — The results of the six series of tests detailed above indicate that the percentage of control is about the same for the liquid spray as for the dust. In beds where very frequent watering is necessary, there might be some advantage in the liquid sprays, because when once dried on the leaves they adhere much better than the dust. The dust, however, has the advantage that it comes up and covers the lower side of the leaves better than the liquid. The dust can be applied more quickly, but thorough dusting with a rotary hand duster is very hard work if continued for any length of time. The dust is also irritating to the nose, eyes and throat. Cheapness of materials and machines is in favor of the liquid sprays. Altogether, the choice between liquid and dust seems to be a matter of personal taste.

Home-made v. Commercial Copper Sprays. — In the control obtained there seems to be very little difference between the results secured by the home-made preparation and the commercial sprays such as Pyrox or NuRexo. Home-made Bordeaux has the advantage of cheapness, while the commercial sprays have the advantage of more rapid preparation for application. If a grower has large beds which require frequent application, certainly it would be more satisfactory to prepare his own fungicide. For small beds the commercial sprays might be more satisfactory. Clinton and McCormick (2: 386), after experimenting with Bordeaux mixture and a number of commercial copper sprays, recommend home-made Bordeaux mixture as being cheaper and more effective than other copper fungicides. They tried dust on only one bed and had no wildfire there on either the treated or untreated plot.

Best Time of Day for Application. — Dust should be applied preferably in the early morning when the plants are wet, or after watering. When the copper sulfate and lime in the dust come in contact with water, they unite to form Bordeaux mixture, which dries on the leaf and adheres with at least a part of the tenacity of the liquid Bordeaux. If, however, the dust is applied to the dry plant and water then applied, even when the Bordeaux is formed it is mostly washed from the leaf before it dries. Liquid sprays should be applied when the plants are dry, because the spray is thus not diluted with water already on there and because less of it drips from the leaves at that time.

Absolute v. Partial Elimination of Wildfire. — It will be noted in the tables given above that in almost all of the sprayed and dusted plots a certain amount of wildfire appeared. Only in a few tests has it been possible to eliminate all infection. In the first five series of tests, however, it should be remembered that sprinkling cans full of water teeming with the parasitic bacteria were sprinkled over all the plants every three or four days. Such a method of inoculation is much more drastic than would occur under natural conditions in the beds of the average tobacco grower. If the treatment here recommended is faithfully carried out by the grower, we believe that in the large majority of cases no wildfire will be found in his beds. Even if there are occasional infected plants in the bed, the treatment is not a failure. The removal of diseased plants from the field will be much easier if there are only a few of them. Even if they are not all removed, the amount of final infection may be expected to be less if there are only a few centers from which it can spread.

Will Clean Beds give Clean Fields? — Clean beds are not an absolute guarantee that no wildfire will appear in the fields planted from such beds. During the season of 1922 in at least six instances the writers had convinced themselves by thorough and frequent inspection that the seed-beds of certain growers were entirely free from wildfire, but the disease developed later in the fields planted from these same beds. (Read the paragraph above on "Dissemination" for more details.) Such cases, however, should not encourage any one to believe that no benefit is derived from keeping the seed-bed clean. The worst and the most wide-spread field infections have usually come from the bed. Starting with clean plants in the field is not the whole measure of success, but it is a long start toward it.

Success by Practical Growers. — During the season of 1922 the writers made frequent inspections and kept careful records on the seed-beds of a number of growers. Untreated checks were not left in any case, and for this reason the results are not entirely convincing. They were unable to find wildfire in any of these beds where the plants were kept constantly covered with the fungicide. On the other hand, it did appear in the beds of many who dusted or sprayed a few times, or started to treat only after the disease became evident, or used only a scant amount of material.

Value of an Arsenical in the Fungicide. — In the first test some of the fungicides, both the dry and the liquid, contained an arsenical. This arsenical not only was found to be of no value for the control of wildfire, but frequently caused injury to the plants. There seems to be no reason for adding an insecticide.

Dust Burn and Spray Injury. — Heavy application of dust or copper spray frequently causes some injury to the plants. It has been commonly noted in the experimental beds at Amherst that the plants in the check plots appear healthier (except for the wildfire) and larger than in the treated plots. Growers have frequently called the writers' attention to this condition in their beds. Sometimes it is much more marked than at other times. Frequently it cannot be observed at all. Certain conditions of the plant or its environment must be responsible for this variation, but it is not as yet known just which conditions favor and which prevent such injury.

Dust burn is evidenced on the leaves by small dead spots of one-eighth inch diameter or less, colored white, brown or darker to black, irregular in outline, commonly bordered by indefinite blanching of the immediately surrounding tissue. This border, however, is narrow and inconspicuous and fades away indefinitely into the normal green leaf. It is quite different and easily distinguished from the halo about the wildfire spot. The leaf area about the spot is also commonly distorted or puckered into radiating wrinkles. Where excessive amounts of dust are used, whole leaves or entire plants may exhibit this wrinkled, distorted appearance without central dead spots. This results in dwarfing.

Spray injury resulting from the liquid fungicides is indicated by larger dead areas in the leaves on the margins, tips or other places where the liquid stands in drops.

Injury from either dust or liquid spray has never been serious and at most has resulted only in slightly slower growth of the plants in the beds. The plants immediately recover after being set in the field. The injury is never of sufficient importance to discourage the application of dust or liquid spray.

Secondary Benefits. — Practical growers have frequently called attention to the absence of flea beetle in the treated beds. One prominent grower has stated that he would spray whether he had wildfire or not because the beds were free from these insects. Copper-lime fungicides are known to repel flea beetles.

Frequently when the plants are thick in the bed and kept damp, they rot off at the base of the stem. It has been commonly noticed that this condition does not occur when the beds are properly treated with a fungicide.

Conclusion. — Any grower who will start when the plants are no larger than a dime and keep the leaves covered at all times with copper-lime dust or any other good copper fungicide can control wildfire in the seed-bed. We agree with Clinton and McCormick (2: 386) in the following quotation except that we would include dusting as well as spraying: —

> We are convinced that spraying of tobacco beds should be made one of the routine practices of tobacco growing as long as there is danger from wildfire. . . . We have evidence that plants thoroughly coated with the spray do not become infected anything like unsprayed plants in the same bed. Spraying to be most effective, however, must start before the appearance of wildfire and be continued until the end of the transplanting season. We would start with the young plants that have just taken root and whose largest leaves are about the size of a thumb nail. . . . *Spraying, we believe, is the only remedy that prevents spread of the wildfire in a seed-bed no matter what the source of its introduction.*

Destroying Diseased Areas in the Bed.

It is characteristic of the disease that when it is first found in the beds it does not occur uniformly over the bed, but is usually found in round spots which may be from a few inches to several feet in diameter, depending on the length of time during which the spot has been spreading. If only one or a few spots are found in a bed, it is sometimes possible by prompt action to keep the rest of the bed clean. This may be done by immediately destroying the diseased spots by drenching them with a 1/10 formaldehyde solution. Not only the spot but all the plants within a foot or two beyond it must be killed. This treatment was successful in preventing further spread in one bed in Sunderland, in one in Hatfield and two in Windsor, all of which were under the writers' constant observation during the summer. Glass should be removed from all plants of the bed which it is desired to save, because if they are left on, the fumes of the formaldehyde will spread through the bed and burn the leaves with which they come in contact. Plants should not be hoed out or pulled out before treatment, since this only serves to spread the trouble. Plants around the burned-out areas should be watched carefully for further spread. Spraying or dusting should also be started at once if it has not been practiced previously.

Removing All Plants from a Diseased Field and resetting with Healthy Plants.

Two fields have been under the careful observation of the writers during 1922 in which this practice was adopted, but in both cases it resulted in failure. In one field in Hadley and one in North Hadley, when the plants were about a foot high, they were found to be practically all infected. All were removed from the field and after it had been harrowed the field was reset with healthy plants. In both cases before the new plants were ready to harvest, they became almost as badly infected as the old ones. Apparently the pathogen remains in the soil and under favorable conditions will infect the new crop. The grower can gain by this practice only when the weather changes for the better during the growth of the second crop. The same principle would apply also to the restocking of a field where only a part of the plants were diseased. This was tried on a large scale by a grower of shade tobacco at North Hadley, who removed only the diseased plants (about 10 per cent) and restocked with healthy plants, but failed to control the disease. The following experiment bearing on this point was tried at the Windsor station: —

Experiment 15. — In one plot nineteen diseased plants were found ten days after setting. They were all removed and replaced by healthy plants. Eleven out of the nineteen resets developed wildfire later.

During 1921 a number of growers practiced either partial or complete restocking with healthy plants after diseased ones were removed, and little or no wildfire appeared later in the field. The same was true of some Connecticut fields in 1922. This apparent control may have been due to weather conditions which were not favorable for infection of the plants of the second setting. At any rate the results were contrary to most of our experience of 1922. In view of the latter it seems questionable whether restocking should be recommended.

Roguing without Resetting.

When only a few plants in a field are diseased, it is probably best to remove them from the field and leave empty the places from which they were taken. This was tried with success by three growers in North Hadley whose fields were under the writers' observation during the present season. Other growers have told the writers that they kept wildfire in check by this method.

Experiment 16. — In a plot at the Windsor Station, where five plants were found to be diseased ten days after setting, they were all removed and the places not filled. The surrounding plants were inspected regularly and in two cases they became infected later.

In a later experiment, where the plants were about $1\frac{1}{2}$ feet high, the diseased ones were removed and not replaced. Before harvesting, however, wildfire had appeared on the adjacent plants and had spread through four to six plants to the windward and along the row.

It is reasonable to believe that bacteria which came into the soil from the original diseased plant would have less opportunity for further infection if no plant replaced the diseased one which was removed. Certainly the danger of surrounding plants becoming infected is diminished by removal of infected ones from the field. On the whole, there is no question but that this practice of roguing will help to a great extent where there is only a light infection in the field, especially if the plants are pulled when small. After plants are half-grown, however, under favorable conditions the disease may spread in its customary manner, and it may be necessary to remove plants or infected leaves from plants for some distance around the original point of infection.

Picking off Diseased Leaves.

If the plants are large and infection is light, a certain amount of benefit may be derived from removing all diseased leaves and carrying them from the field. The principle of this measure is the elimination of as many as possible of the centers of spread. Then when the rains come the number of bacteria splashed to the healthy leaves will be greatly reduced. This method was tried by Anderson on a 4-acre field in Whately.

Experiment 17. — Infection in this field started from about six to eight rows near the east side, which had been planted from a diseased bed. At the time when the experiment was started a majority of the plants in these rows were diseased, and it had spread more or less to plants on adjacent rows. There was practically no infection on the west half. On June 30 all diseased leaves were picked from the east half (forty-eight rows). No attention was paid to the west half. On the badly infected rows mentioned above a large basketful of leaves was taken from each row, some of the plants being left almost without leaves. It was picked again four days later, the weather having been very rainy during the last month. Probably as many leaves were removed the second time as during the first picking. It was picked over at short intervals five times afterward, and with each picking the number of diseased leaves decreased, until on July 26 hardly a diseased leaf could be found. After the heavy rains of the last few days of July and the first of August, however, wildfire began to appear again on the picked side of the field, but to a greater extent beyond the forty-eighth row, where no picking had been done. The field was harvested on August 8. On that date the picked and unpicked sides of the field were inspected by Mr. Arthur Hubbard, W. H. Davis, D. Potter, C. M. Slagg, Dr. James Johnson and the writer, and it was the opinion of all that the unpicked side showed much more wildfire than the picked side. Mr. Hubbard was of the opinion that the east half would not have been worth harvesting if the disease had been left to take its natural course. The loss in weight from removal of the diseased leaves was not serious. As previously mentioned in this report there was good evidence that when infection began again during the first few days of August it came from bacteria which were in the soil. This source of infection cannot be eliminated and will probably prevent this method of control from ever being entirely successful. In view of the fact, however, that the season of 1922 was usually favorable to the spread of wildfire, the results of the experiment are encouraging.

A similar experiment was conducted on a Round Tip plot at the Windsor Station and with similar results. Growers who tried picking off affected leaves are divided as to their opinion of the practical value of the method. The degree of success varied according to the kind of tobacco and method of harvesting. Chances of success are better in primed tobacco because after harvesting starts the leaves are picked so rapidly that the disease does not have an opportunity to get a good start, and it also becomes increasingly difficult for the germ-laden soil to splash to the first leaves. Field observations on the picking of leaves during 1922 lead to the following conclusion: —

On the Shade Cuban, favorable results were almost uniformly obtained and the disease was practically eliminated. On Havana and Round Tip, where diseased leaves were removed, there was a considerable variation in the results, with a majority of fields showing decided benefit. On Broadleaf there did not seem to be anything gained by picking off the leaves.

For any one who contemplates this method of control it is recommended that (1) the first inspection be made as soon as the plants are established in the field; (2) the leaves be picked off twice a week as long as any diseased ones can be found; (3) sand leaves of diseased plants be picked also.

Clinton and McCormick (2: 396) also experimented with removal of diseased leaves and as a result were somewhat doubtful as to the benefits.

Dusting the Plants in the Field.

The value of dusting the plants in the field with copper-lime dust was tried by two Massachusetts growers under the writers' supervision during the season.

Experiment 18. — Twenty-four acres in Hadley were first dusted with a four-row traction duster, which was furnished by the Niagara Sprayer Company, on July 6, when the plants were 12 to 18 inches high. The infection was bad in parts of the field when the experiment was started. Four rows were left without dust. There were very heavy rains on the 8th and the second application was made on the 13th and 18th. During July there was very little spread of wildfire in any fields and the plants grew enormously. By the first of August the plants had grown until the machine could not be drawn through the field without serious damage to the plants, and therefore no more applications were made. There was considerable spread of the disease during August, until the crop was harvested about the middle of the month. A comparison of the treated and untreated rows at that time showed no difference in the amount of disease. No accurate counts were made, but a cursory examination while walking between the rows did not indicate any benefit from the two applications of dust. It was also noticed that there were dust-burn spots on the treated leaves similar to those which have been previously described as occurring in the beds. The owner feared that if the dusting were continued, the spots might affect the market of the crop.

Experiment 19. — Another grower in North Hadley dusted two fields with the machine used in Experiment 18, but more frequent applications were made. Wildfire was not controlled, the results being similar to those of Experiment 18.

Experiment 20. — On one of the Windsor Station plots Round Tip tobacco, which showed a heavy mixed infection of wildfire and angular leaf spot on the bottom two or three leaves when the plants were from 1 to 1½ feet in height, a copper-lime dust was twice applied to four rows, with a five-day interval between the first and second treatments, no rain falling in the interim. Six rows were left untreated for comparison. For about two weeks after treatment, the spread of the disease in the dusted rows was practically nil, while in the undusted rows it spread steadily and very rapidly. After this time three rainy days ensued, but purposely no more dusting was done. At harvest time it was found that the amount of wildfire on the dusted rows was only 15 per cent (estimated from partial count on cured tobacco) less than on the rows which had not been dusted.

No doubt, if the leaves in the field could be kept covered with dust all the time, the disease could be controlled, but this would require more frequent applications, and when the plants become large it cannot be done without considerable breaking of the leaves. Control by this method is probably possible, but not economically so. Further experiments, however, are planned. It was found that the dust adhered much better if applied early in the morning while the plants were still wet with dew.

Spraying with Bordeaux Mixture in the Field.

Bordeaux mixture was tried with the idea that it would adhere to the leaves more tenaciously and hence so many applications would not be necessary as when dust was used.

Experiment 21. — A field of 12 acres in North Sunderland was sprayed on July 11 with 4-4-50 Bordeaux. No further applications were made because the owner feared that the material would remain permanently on the leaves and affect the sale of the crop. An examination on August 14, when the crop was being harvested, showed that it was present in large enough quantity on many of the leaves to give them a decidedly blue cast. A comparison of the sprayed and unsprayed rows showed no difference in the amount of the disease.

Clinton and McCormick (2: 395) experimented with Bordeaux mixture in a preliminary way and found that it retarded spread of the disease, but they did not consider it practical because of cost and unknown effect of the spray on the quality of the mature leaf.

A few Connecticut growers tried spraying in the field in 1921 and reported good control. This year several growers of sun as well as shade grown tobacco sprayed plants in the field from one to six times, until the plants were too large to permit of further treatment, but the results have not been encouraging in the case of sun-grown tobacco. While the treatment seemed to check the disease for a time, later in the season after the plants had grown too large to continue the treatment, wildfire spread rather rapidly, and at harvesting little difference could be observed between the sprayed and unsprayed areas in the same field. In the case of one grower who had a rather bad field infection when the plants were small, the use of a Bordeaux mixture applied twice on part of the field when the plants were small checked for a long time any further spread of the disease, and at harvesting time the part of the field sprayed twice showed much less wildfire than the unsprayed part of the field.

Bordeaux mixtures are cheaper and under field conditions remain on the leaves a longer time, which is of course desirable from the infection protection standpoint, but a disadvantage when the plants are more than half-grown, as it remains on the leaves and the blue color is undesirable after the cure.

Another factor operating against the efficiency of dusts or sprays in the field is that after the plants are about half-grown it is a practical impossibility to operate a duster or sprayer to advantage, and one is obliged to stop the treatment at what might be termed the critical period, as it is well known that there is often a heavy wildfire infection just prior to maturity.

It is believed, however, that some benefit might be obtained from dusting or spraying when the plants are small and until they are about a foot high, particularly if spraying or dusting were combined with picking off diseased leaves, and the spraying or dusting repeated at very close intervals, say two or three times a week for a period of two weeks or so.

It is believed that the application of dusts or sprays to tobacco in the field is worthy of further consideration both by the growers and the station, and next season more detailed experiments along this line will be carried on.

At present, however, the evidence at hand is not very favorable for this method of control.

THE OUTLOOK FOR 1923.

The question now most frequently asked by the grower is: What can we expect from wildfire in 1923 and in the following years? Will it continue as prevalent and troublesome as it has been in 1922? Will it become worse after our land is thoroughly infested with the germ? Or will it gradually disappear? Frequently tobacco growers have told the writers that they would stop raising tobacco if they thought the disease would continue to be as serious as it has been during 1922. No man can predict its future behavior with certainty or anything which approaches certainty, but we can base some judgment on (1) what we know about its relation to weather conditions and (2) its behavior in States where it has been present longest.

We know that the disease can spread only when the rains are long continued or follow each other in close succession, i.e., when the water remains for long periods on the leaves. The summers of 1921 and 1922 were for the most part ideal in this respect for the spread of the disease. They have not been average summers for the Connecticut Valley. The disease will not be as destructive during an average growing season. We do not believe that wildfire will soon disappear from the valley, but during a dry summer it might not cause any damage. After a succession of unfavorable seasons the sources of infection might be so reduced that it would cause little trouble even with the return of a summer favorable for its spread. The above opinion is supported by the course which the disease has taken in the South. Five years ago it was destructive there. In 1921 the season was very dry and the injury from wildfire was slight. The season of 1922 is said to have been not unusually dry, but the disease has not returned to any extent. Our advice to the Connecticut Valley grower is to plant as usual, take a chance on the weather, but to omit no precaution recommended against wildfire.

CONDENSED RECOMMENDATIONS FOR CONTROL.

There is no one measure by the use of which a tobacco grower may be assured of raising a clean crop. As long as wildfire is in the valley, he must start before the seed is planted, be ever on the alert and ready to put into practice any part or all of the season's program which may now be briefly summarized: —

1. Select seed only from plants known to be free from the disease. If possible, go a step farther and take only from fields known to be disease-free. Protecting the flower heads with bags may be useful. Old seed is less likely to be contaminated.

2. If there is doubt about the seed being sterile, soak it in a cheesecloth bag for fifteen minutes in $1/1000$ corrosive sublimate, wash and spread out to dry.

3. If possible, locate seed-beds only on land where there was no wildfire during the previous year and where there has been no opportunity for contamination.

4. Sterilize soil with steam at 100 pounds pressure for thirty minutes, or with formaldehyde $1/50$ at the rate of one-half gallon to the square foot. It is safer to sterilize walks also. Spring sterilization is safer than fall sterilization.

5. Drench boards and sash with formaldehyde $1/50$. If cloth is used, it should either be new or should be boiled in water or treated like the boards and sash. If sash and plank are new or have never been used for tobacco beds, they need not be sterilized.

6. Keep the plants covered with copper-lime dust or a copper spray such

as Bordeaux mixture at all times, from the stage when they are as large as the finger nail until setting is completed.

7. Remember that the germs can be carried from one bed to another on the hands, tools, sash, etc., and avoid such chances.

8. Adopt a system of bed management which will keep the leaves moist during the shortest length of time compatible with the production of good plants.

9. If the disease appears in certain spots in the bed, these spots, along with a broad margin of plants which appear healthy, should be killed by drenching with 1/10 formaldehyde.

10. Pull plants for setting only from disease-free beds.

11. Starting as soon as the plants have recovered and begun to grow in the field, make frequent inspections and remove every diseased plant from the field.

12. Do not work in a field where there is any wildfire while the leaves are wet.

13. Removal of diseased leaves at intervals of three or four days, where the infection when first found is light, will reduce the number of centers of spread and may materially reduce the percentage of wildfire in the crop when harvested.

14. Rotate tobacco with other crops if practicable.

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COMBATING APPLE SCAB

SPRAYING AND DUSTING EXPERIMENTS IN 1922

By WEBSTER S. KROUT

The scab fungus of the apple affects seriously the McIntosh Red, particularly as it is grown in the eastern apple region of the State. Nowhere in the State has scab yielded completely to the protective spraying and dusting methods commonly followed by apple growers. The Experiment Station started work on disease control in the fall of 1920. The outstanding fact to date is that of a high degree of control even in spite of adverse weather conditions. This bulletin gives the record of the 1922 operations, together with concise recommendations for protective treatment against the disease.

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BULLETIN No. 214.

DEPARTMENT OF BOTANY.

COMBATING APPLE SCAB.

SPRAYING AND DUSTING EXPERIMENTS IN 1922.[1]

BY WEBSTER S. KROUT.

Introduction.

The fact of control by both spraying and dusting is outstanding at the end of the second year's field study of this fungous disease. Weather conditions in both 1921 and 1922 were most adverse to successful spraying and dusting, and most favorable to scab infection, yet despite these handicaps almost perfect control was obtained.

These investigations were started in the fall of 1920. In the fall of 1921 a report of the results of the first year's work was published through the Extension Service of the College in a pamphlet entitled "Apple Scab and its Control." This bulletin presents to the practical orchardist a similar report for 1922.

The field work has been conducted in three orchards under the direct supervision of the writer. In three other orchards he was present whenever possible. The spraying experiments were in the orchards of Stephen Sabine of Groton and Harry L. Knights and H. L. Frost of Littleton. The dusting experiments were conducted in the orchards of Harry L. Knights and H. L. Frost of Littleton, A. N. Stowe of Hudson, George A. Marshall of Fitchburg and R. J. Fiske of Lunenburg. Especially helpful was the co-operation of J. W. Ames, superintendent of the Knights farm, Roy C. Wilbur, superintendent of the Frost farm, John J. Collins, superintendent of the Stowe farm, and the officers of the Nashoba Fruit Producers Association.

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[1] The writer is indebted to Prof. A. Vincent Osmun, head of the Department of Botany of the Massachusetts Agricultural Experiment Station, for many helpful suggestions during the progress of this study.

Apple Scab.

Apple scab presents one of the most serious problems of the commercial apple grower of Massachusetts. The disease is caused by a fungus which attacks the leaves, flowers, fruit, pedicels and twigs. It may attack any variety of apples, but is exceptionally severe on the McIntosh.

Every orchardist should endeavor to familiarize himself with the first symptoms of apple scab as they appear on the leaves, so that the disease may not reach the epidemic stage before he realizes the danger. Scab usually appears first on the lower side of the leaves as grayish or olive webby spots or blotches, darker than the normal surface of the leaf. The color deepens with age to dark brown or black. The spots on the upper surface of the leaves are first noticed as yellowish green discolorations, gradually deepening with age through olive brown to black. They are velvety, somewhat definite in outline, smaller than spots on the lower side, and have a tendency to become raised or convex.

The Causal Fungus.

The scab fungus passes the winter on the dead leaves, under the trees. In the autumn after the leaves fall the fungus continues growing, penetrating the interior of the leaf. Sometimes, in November, it begins to form the flask-shaped bodies (perithecia) in which mature winter spores (ascospores) are developed by the following spring. During the rainy periods of spring these spores are discharged, and, being extremely light, are carried upward by the air to the under surface of the leaves. The scab spots produced by this infection appear from eight to fifteen days later. These spots, almost as soon as they are noticeable, produce the summer spores in great quantities. These spores cause rapid spread of the disease.

Table I. — *Dates of Discharge of Winter Spores and of the First Appearance of Scab in 1921 and 1922.*

	1921.	1922.
First discharge of winter spores	April 26	May 2
First appearance of scab	May 12	May 18
Last discharge of winter spores	June 10	June 15

During both years the first spots were discovered on the lower side of the leaves at the time of the calyx spray. In other words, the first spots appeared as the petals were dropping.

Spraying Program for 1922.

A series of plots in triplicate were laid off in the three orchards previously mentioned. The sprays used were home-made Bordeaux mixture alone, home-made Bordeaux mixture and liquid lime-sulfur, home-made Bordeaux mixture and dry lime-sulfur, a 4–50 and a 3–50 dry lime-sulfur, liquid lime-sulfur, and liquid lime-sulfur plus lime.

Powdered arsenate of lead, at the rate of 2 pounds to 50 gallons of spray, and 40 per cent nicotine sulfate, at the rate of three-eighths pint to 50 gallons of spray, were used with all the different spray materials in the delayed-dormant, pink and calyx. In the fourth summer spray arsenate of lead was used but the nicotine was omitted.

In the Sabine and Knights orchards the plots were rectangular, 4 rows of 6 trees each, except the check at Sabine's which had 16 trees, and the Bordeaux–dry lime-sulfur plot at Knights' which had 20 trees. In the Frost orchard the plots consisted of single rows of 8 to 11 trees. The data were taken from 5 typical trees of the two middle rows of each plot in the Sabine and Knights orchards; and in the Frost orchard, from 5 typical trees of each row. The trees of each of the three sprayed orchards were approximately twelve years old.

Treatment of Plots.

All plots, except the checks, were given the delayed-dormant application. The plots in the Sabine and Knights orchards were sprayed with a 1–10 liquid lime-sulfur plus arsenate and nicotine. The plots in the Frost orchard were sprayed with a 15–50 dry lime-sulfur plus arsenate and nicotine. Plots 1 to 8 were conducted in each of the three orchards. Plots 9 to 11 were conducted only in the Frost orchard. The plots in the Sabine orchard were the only ones given the fifth summer spray. The detailed treatment of plots follows: —

Plot 1. — Check, unsprayed with fungicides. The same insecticides were used as on the other plots. A single check plot was used in each of the Sabine and Frost orchards. In the Knights orchard two check plots were necessary, because the Bordeaux plot was located in a separate block of trees.

Plot 2. — A 3–10–50 home-made Bordeaux mixture[1] for the pink spray, and a 1–50 liquid lime-sulfur for the calyx and following sprays.

Plot 3. — The same as plot 2, except that dry lime-sulfur was substituted for the liquid.

Plot 4. — 1–50 liquid lime-sulfur.

Plot 5. — 4–50 dry lime-sulfur.

Plot 6. — 1–50 liquid lime-sulfur plus 6 pounds of lump lime to 50 gallons of spray.

Plot 7. — A 3–10–50 home-made Bordeaux mixture for the pre-pink and pink, and liquid lime-sulfur for the calyx and succeeding sprays.

Plot 8. — A 3–10–50 home-made Bordeaux mixture only.

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[1] Directions for making Bordeaux mixture may be obtained by applying to the Extension Service, Massachusetts Agricultural College. Ask for Extension Leaflet No. 33.

Plot 9. — A 4–50 dry lime-sulfur for the pre-pink, pink and following sprays.

Plot 10. — A 3–50 dry lime-sulfur plus arsenate and nicotine.

Plot 11. — A 3–50 dry lime-sulfur plus nicotine sprayed on the trees, allowed to dry, and then the arsenate applied.

Time and Manner of Spray Applications.

TABLE II. — *Time of Application of Sprays for 1921 and 1922.*

Application.	1921.	1922.
Delayed-dormant	April 4– 6	April 13–19
Pre-pink	– –	April 28–May 3
Pink	April 25–27	May 3– 8
Calyx	May 10–12	May 16–20
Fourth summer	June 6– 8	June 9–22
Fifth summer	– –	June 25–31

As previously explained, two additional applications, the pre-pink and fifth summer, were made on some of the plots in 1922. Power sprayers which maintained approximately 200 pounds pressure were used, with spray rods equipped with the regular 45° Friend angle nozzles. By holding the rod close to the ground and in such a position as to shoot the sprays upward, the under surface of the lowest leaves was thoroughly covered. As these are the first leaves attacked by the scab fungus, it is exceedingly important that they be well covered at the pre-pink and pink applications.

DISCUSSION OF RESULTS OF SPRAYING.

Throughout most of the season weather conditions were exceedingly favorable for scab infection.

It will be noted in Tables IV, V and VI (pages 40 and 41) that all of the sprays gave exceptionally good control. In fact, many of the sprayed plots produced 100 per cent marketable fruit, whereas some of the checks produced fruit 100 per cent scabbed. There was not a single scab-free apple on the 16 check trees in the Sabine orchard, and 95 per cent were so badly scabbed that they were unmarketable. In the Knights orchard the situation was nearly as bad, 96 per cent of the fruit being scabbed and 69 per cent unmarketable. In the Frost orchard infection was not quite as severe, only 41 per cent of the fruit being scabbed.

Only small and probably insignificant differences were found in the results obtained from the different fungicides in so far as control of the scab fungus is concerned.

Importance of the First Spray Applications.

The dissemination of scab spores is most rapid about the time of the *pink* application. This is, therefore, the most important spray and should be so timed that it will be on the foliage, blossoms and pedicels of the blossoms before the winter spores are discharged. Observations of the writer *indicate that most growers who fail to control scab apply the pink spray too late in the season.*

In some places a *pre-pink* spray is used in order to make certain that the fungicide is on the leaves before the scab spores are discharged. Explained in the most simple terms, this means setting the pink spray ahead from seven to ten days. It is a spray applied approximately midway between the delayed-dormant and the pink. At that time most of the cluster buds are still closed, and a few only of the most advanced blossom buds show slight amounts of pink. Tables IV, V and VI, plots 7 and 9, show that the series of plots on which the pre-pink spray was applied yielded exceptionally high percentages of both clean and marketable fruit.

If the orchardist were positive that the pink application could be made before the discharge of the winter spores, it would be unnecessary to use a pre-pink spray. The pre-pink application is intended primarily to eliminate this uncertainty connected with the pink treatment. The cost of the spray material at this application is a small item, as the arsenate and nicotine are omitted. As this application has been tested one year only in this State, the writer hesitates to recommend it to the small orchardist. To any orchardist who has three or more days of spraying at the pink application, it is to be recommended without hesitation.

Home-made Bordeaux and Lime-Sulfur.

A 3–10–50 home-made Bordeaux mixture used alone for all applications russeted the fruit and burned the foliage so badly that its use in this way will be discontinued. Foliage burn due to the Bordeaux was not evident until the latter part of the season.

For two years, a 3–10–50 home-made Bordeaux mixture for the pink spray, followed by a 1–50 liquid lime-sulfur for the calyx and succeeding sprays, has given the most satisfactory results. From Tables IV, V and VI it will be seen that this combination in Sabine's orchard produced 98 per cent marketable fruit, but fell slightly lower than some of the other plots in clean fruit. In the Knights and Frost orchards it produced 100 per cent marketable fruit.

Some of the fruit sprayed with the Bordeaux–liquid lime-sulfur combination described above was russeted slightly. The writer questions whether this was caused by the Bordeaux at the pink spray or by natural conditions, as about the same amount of russeting occurred on some of the unsprayed trees. Also, no russeting occurred on similarly treated plots in 1921. The russeting was slight and did not injure the sale of the fruit except where the apples were sold to a fancy trade. In 1921 lime-sulfur burned the blossom buds badly.

A test was made to determine if dry lime-sulfur used with home-made Bordeaux mixture was as effective for the control of scab as the liquid form. Tables IV, V and VI, plots 2 and 3, show that the dry form was practically as good as the liquid, except in the Sabine orchard, where for some unexplained reason the Bordeaux–dry lime-sulfur plot yielded only 49 per cent clean fruit and 90 per cent marketable fruit. The fact that the total yield of this plot was exceptionally low may justify leaving it out of consideration.

Liquid Lime-Sulfur versus Dry Lime-Sulfur.

For two years dry lime-sulfur has given as good control of scab as the liquid form (Tables IV, V and VI). Four pounds of the dry form in 50 gallons of water have been used for all sprays except the delayed-dormant in most of the work, but judging from this year's results 3 pounds will give as good results. Some growers use only 2 pounds in 50 gallons, but in the opinion of the writer this is too dilute.

Dry lime-sulfur has the advantage of less bulk, and it is claimed that the fungicidal value is not injured by freezing. Both the dry and liquid forms of lime-sulfur used with lead will burn the foliage under certain conditions, but judging from the data at hand the liquid form seems to burn slightly more than the dry.

The Cost of Spraying.

In figuring the cost of spraying the writer has used the data from the experimental plots of 1922. It is assumed that there are 30 twelve-year-old McIntosh trees to the acre. Dry lime-sulfur and insecticides are used as indicated in the suggested spraying schedule for 1923: dry lime-sulfur, 15 pounds to 50 gallons of water for the delayed-dormant, and 4 pounds to 50 gallons of water for the four later applications; powdered lead arsenate, 2 pounds to 50 gallons of spray; and nicotine sulfate, three-eighths pint to 50 gallons of spray. Four gallons of spray are allowed for each tree. The cost of lime-sulfur is placed at $10\frac{1}{2}$ cents per pound; powdered arsenate of lead at 14 cents per pound; and nicotine sulfate at $14 per gallon. Spraying with either liquid lime-sulfur or Bordeaux mixture costs slightly less than with dry lime-sulfur.

Table III. — *Cost of Spraying One Acre of Apple Trees.*

Applications.	Material.			Labor.		Total.
	Dry Lime-Sulfur.	Lead Arsenate.	Nicotine Sulfate.	Man.	Team.	
Delayed-dormant	$3 78	$0 67	$1 57	$0 70	$0 30	$7 02
Pre-pink	1 00	–	–	70	30	2 00
Pink	1 00	67	1 57	70	30	4 24
Calyx	1 00	67	1 57	70	30	4 24
Fourth summer	1 00	67	1 57	70	30	4 24
Total for five applications	$7 78	$2 68	$6 28	$3 50	$1 50	$21 74

Dusting Program for 1922.

The use of dusts for the control of apple scab is new in this State. Prior to 1921 the writer knew of only one dusting machine in the eastern part of the State, and that was used for dusting peaches. In 1921 dusting experiments were begun by the station in three orchards. The writer and growers who co-operated were inexperienced in the art of dusting, and consequently the dusts were not applied as well as they might have been. As a result, dusting compared very unfavorably with spraying.

In 1922 a number of growers bought dusting machines. With the experience of the previous year, and willingness on the part of growers to co-operate, extensive plans were made to test the efficacy of dusting materials for the control of apple scab. Accordingly, five orchards, previously mentioned, were chosen in which to locate the experiments. Two dusts, sulfur and a copper-lime-arsenate dust, were used in each orchard. Checks were used in all cases. The plots were all large, one of them containing 179 trees. Only McIntosh trees were used.

It will be noticed that there was no nicotine in any of our dusts. Nicotine makes a dust expensive, and the manufacturers state that it is difficult to manufacture a satisfactory sulfur dust high in sulfur with sufficient nicotine in it. As it happened, no nicotine was needed on any of the plots, but it was planned to spray with a nicotine solution or dust with a nicotine dust should infestation with sucking insects become serious.

Five representative trees of each dusted plot in the Marshall and Stowe orchards, 7 in the Knights orchard and 6 in the Frost orchard were chosen from which to take data. Also 3 representative trees of each undusted check in the Marshall and Knights orchards, 2 of one check in the Stowe orchard and 3 of the other (Table VII, plot 12) and 2 in the Frost orchard were chosen from which to take the data (Tables V, VI and VII, pages 40 and 41). The data of the Fiske orchard are not given as the trees were young and the yield exceptionally low.

Treatment of Plots.

Plots 13 and 14 in all the orchards were given the regular delayed-dormant spray with lime-sulfur. The plots in the Stowe orchard were given three dust applications, — the pre-pink, pink and fourth summer. The plots in the Frost and Fiske orchards had four applications, — the pre-pink, pink, calyx and fourth summer. The plots in the Knights orchard had five applications, — the pre-pink, pink, calyx, fourth and fifth summer. The plots in the Marshall orchard had nine applications, — the pre-pink, pink, calyx and six subsequent applications. The detailed treatment of plots follows: —

Plot 12. — Check untreated with fungicides, but sprayed with the usual insecticides.

Plot 13. — Sulfur dusts. The ordinary commercial dusting sulfur without insecticides was used for the pre-pink, fifth, sixth and seventh summer applications.

A sulfur dust, composed of 85 parts sulfur and 15 parts arsenate of lead, was used for the pink, calyx and fourth summer dusts.

Plot 14. — Copper-lime-arsenate dust for the pre-pink, pink and fourth summer applications only. An 85–15 sulfur dust was used at the calyx application, and dusting sulfur for treatments after the fourth summer application.

Time and Manner of Application.

The dusts were applied at approximately the same time as the sprays (Table II). Two different makes of power dusting machines were used. *The dusts were applied from two sides of the trees while the leaves were wet.* Dusting was started at 5 A.M. and continued until about 8 A.M. The best distribution of dust through the tree was accomplished by giving the hose a circular or a quick upward and downward movement. Care was taken to hit the lower leaves, especially at the pre-pink and the pink applications. The engine and duster should be on a low wagon or truck built especially for the purpose, so that the operator may shoot the dusts upward through the tree. Where rows of trees are too close together, this will hinder the operation of the duster.

Discussion of Results of Dusting.

In evaluating the results from dusting in 1922 it must be borne in mind that only a single year's work is represented, and that it is, therefore, decidedly unsafe and unsound to draw any conclusions whatever.

The data in Tables V, VI and VII show that the dusts gave excellent control of scab in a year most favorable for the development of the scab fungus. For example, in the Knights orchard the check for the dusts produced only 1 per cent marketable fruit, while the sulfur and copper-lime-arsenate dust plots produced 97 and 99 per cent marketable fruit. In the Frost orchard the check for the dusts produced 68 per cent marketable fruit; the sulfur dust plot, 96 per cent; and the copper-lime-arsenate plot, 97 per cent.

In the Stowe orchard the checks produced from 46 to 48 per cent marketable fruit; the dusted plots, 92 to 97 per cent. Table VII shows that in the Stowe orchard slightly better results were obtained on the younger trees than on the older. This, with the fact that practically all the scabby apples of the dusted plots were found in the tops of the trees, would indicate that the higher the tree the more difficult it is to apply the dust thoroughly. Although the results on the dusted plots were extremely good, it is evident that even better results might have been obtained had the dusts been more thoroughly applied to the topmost parts of the trees.

In several cases where late summer applications of lime-sulfur and dusts were made side by side in the same orchard, the lime-sulfur burned the foliage, while the sulfur dust caused no injury. Later observations showed that where the foliage was burned by the lime-sulfur, from 8 to 20 per cent of the fruit dropped prematurely; while where the sulfur dust was used, practically the entire crop remained on the trees.

It is quite evident that copper-lime-arsenate dust controlled scab more effectively than the sulfur dusts, as in three of four orchards it gave a higher percentage of clean and marketable fruit. *However, it cannot be recommended for apples on account of the russeting of the fruit and the burning of the foliage.* On the other hand, sulfur dusts neither injured the foliage nor russeted the fruit. If kept covered with the sulfur dust, the leaves grow normally and develop a dark green color. *Sulfur dust is cheap and is the only dust that has shown itself worthy of further trial.* It is possible that the copper-lime-arsenate dust may prove useful for the pre-pink and pink applications, to be followed with sulfur dust for the later applications. This combination will be tested another year.

In the Stowe and Marshall orchards there were no experimentally sprayed plots to compare with the dusted plots, but if we may judge from the results which these orchardists obtained on sprayed trees adjacent to the dusted plots, the sulfur dust was equal to the sprays.

The Effect of Apple Scab on the Vitality of the Tree.

The most striking example of what may be expected of an unsprayed McIntosh orchard may be seen on the check plot in Knights orchard (Table V, plot 1). The trees of this plot have not been sprayed with a fungicide since 1920, and in 1921 and 1922 they showed approximately 100 per cent infection of fruit and foliage. The heavy loss of foliage in 1921, in spite of the fact that the trees were fed heavily, caused a very light set of leaves and blossoms in the spring of 1922, and consequently a greatly reduced yield of fruit. Plots 1 and 2, Table V, are located side by side in the orchard. It is planned to shift the check plot in this orchard from its present location to some other part of the orchard in 1923, as permanent injury to the trees is feared.

The Relation of Weather to Spraying.

Spraying should always be done in advance of rain periods, since the fungicide must be on the leaves in advance of the germination of the spores. If allowed to dry thoroughly, efficient sprays do not wash off sufficiently to destroy their fungicidal value. By studying the low barometric areas of the daily weather reports, the grower should be able to predict, with some degree of accuracy, weather conditions two to three days in advance.[1]

Burning of Apple Foliage by Sprays and Dusts.

The foliage of some of the apple trees in the plots was badly burned with lime-sulfur during 1921, while in 1922 very little injury from this material was noticed. The writer believes that weather conditions were

[1] These daily reports may be obtained by addressing the United States Weather Bureau, Boston, Mass.

largely responsible for this difference. Temperature and humidity were quite high when many of the applications were made in 1921, while to a certain extent the opposite was true in 1922. *Apples should never be sprayed when temperature and humidity are both high, as burning of foliage is almost certain to result.*

The amount of spray applied does not seem to be as important a factor in burning the foliage as was formerly thought. In 1922 the writer selected trees in several plots in the Sabine and Knights orchards and thoroughly drenched them with the spray at the pink and calyx applications. At the end of the season the trees showed only slight injury.

Sulfur dusts have never burned the foliage, while burning from copper-lime dust is frequent.

Recommendations for 1923.

Spraying Program.

It should be borne in mind that the spray schedule which follows is based on only two years of experimental work, and therefore is subject to change. Where two or more spray materials are given, the first is preferable and should be used whenever possible.

Delayed-dormant. — Fifteen pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 9 gallons of water.

Pre-pink. — A 3–10–50 home-made Bordeaux mixture, or 3 to 4 pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 49 gallons of water.

Pink. — A 3–10–50 home-made Bordeaux mixture, or 3 to 4 pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 49 gallons of water.

Calyx. — Three to 4 pounds of dry lime-sulfur dissolved in 50 gallons of water, or 1 gallon of liquid lime-sulfur in 49 gallons of water.

Fourth and Fifth Summer. — Same as the calyx. Unless the rainfall of June, July and August is above normal, the fifth summer spray may not be necessary for the control of scab. On the other hand, if these months are rainy and scab is bad, the fifth summer application will be found very profitable.

Three-eighths of a pint of 40 per cent nicotine sulfate to each 50 gallons of spray is used at the delayed-dormant, pink and calyx applications. Also, 2 pounds of powdered lead arsenate to each 50 gallons of spray are used at the delayed-dormant, pink, calyx and fourth summer applications.

Dusting Program.

If a dusting program is to be followed, the delayed-dormant spray should be applied. *Dusting sulfur* should be used for the *pre-pink* and for all applications after the fourth summer dust. A dust composed of 90 parts sulfur and 10 parts arsenate of lead should be used for the pink; an 85–15 dust for the calyx and fourth summer applications. In case sucking insects are bad, it will be necessary to spray the trees with three-eighths pint of 40 per cent nicotine sulfate in 50 gallons of water, or dust the trees with a commercial nicotine dust.

Miscellaneous.

Dry lime-sulfur passes through the spraying outfit better if it be allowed to stand in water about forty minutes before it is poured into the spray tank. Before going to the orchard with each tank of spray material, it is a good plan to weigh out the desired amount for the next tank in a 5 or 6 gallon pail, pour water over it and agitate with a wooden paddle for a few minutes. On returning, the spray tank is filled about two-thirds full of water, the agitator set in motion, the lime-sulfur from the pail poured into the tank, and the tank filled with water. Some growers consider soaking of the material unnecessary before putting it into the tank.

Lime-sulfur should be well agitated before it is applied to the trees as a too concentrated solution will burn the foliage.

Twelve-year-old trees with a height and spread of approximately 20 feet should receive about 4 gallons of spray material with each application.

Follow the spraying system outlined for 1921.[1] It is better to spray against the wind than with it, as less spray materials are wasted and a better covering is obtained.

The engine and duster of the dusting outfit should be on a low wagon or truck built especially for the purpose, so that the operator may shoot the dust upward through the tree. Special effort should be made to hit the extreme tops of the trees. Best results are obtained by giving the hose of the duster a quick circular or an up-and-down movement so as to hit all parts of the tree. Dusting should be done only when the surfaces of the leaves are moist. At least two sides of the trees should be dusted. On trees twelve to fifteen years old, approximately $1\frac{1}{2}$ pounds of dust should be used on each tree at each application.

[1] Extension Circular, "Apple Scab and its Control." This may be obtained by applying to Extension Service, Massachusetts Agricultural College.

Tabulated Results.

Tables IV to VII give briefly the results on the sprayed and dusted plots in each of the orchards during 1922.

Table IV. — *Results on the Sprayed Plots in Sabine Orchard.*

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
1	Check, arsenate and nicotine only .	0	100	5	0
2	Home-made Bordeaux (pink) and liquid lime-sulfur.	84	16	98	0
3	Home-made Bordeaux (pink) and dry lime-sulfur.	49	51	90	0
4	Liquid lime-sulfur	86	14	97	0
5	Dry lime-sulfur, 4-50	86	14	95	0
6	Liquid lime-sulfur plus lime . .	76	24	91	0
7	Home-made Bordeaux (pre-pink and pink) and liquid lime-sulfur.	81	19	96	0
8	Home-made Bordeaux . . .	87	13	97	52

Table V. — *Results on the Sprayed and Dusted Plots in Knights Orchard.*

Plot.	Treatment.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
1	Check for plots 1 to 7, arsenate only .	4	96	31	0
2	Home-made Bordeaux (pink) and liquid lime-sulfur.	98	2	100	0
3	Home-made Bordeaux (pink) and dry lime-sulfur.	97	3	99	0
4	Liquid lime-sulfur	96	4	99	0
5	Dry lime-sulfur, 4-50	92	8	97	0
6	Liquid lime-sulfur plus lime . .	93	7	99	0
7	Home-made Bordeaux (pre-pink and pink) and liquid lime-sulfur.	99	1	100	1
8	Home-made Bordeaux . . .	87	13	95	47
12	Check for Bordeaux and dusts only .	0	100	1	0
13	Sulfur dust	84	16	97	0
14	Copper-lime-arsenate dust . . .	93	7	99	22

TABLE VI. — *Results on the Sprayed and Dusted Plots in Frost Orchard.*

Plot.	TREATMENT.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
1	Check for plots 1 to 11, arsenate and nicotine only.	59	41	90	Negligible.
2	Home-made Bordeaux (pink) and liquid lime-sulfur.	100	0	100	Negligible.
3	Home-made Bordeaux (pink) and dry lime-sulfur.	99	1	100	Negligible.
4	Liquid lime-sulfur	98	2	99	Negligible.
5	Dry lime-sulfur, 4–50	98	2	100	Negligible.
6	Liquid lime-sulfur plus lime . .	90	10	98	Negligible.
7	Home-made Bordeaux (pre-pink and pink) and liquid lime-sulfur.	99	1	100	1
8	Home-made Bordeaux . . .	100	0	100	13
9	Dry lime-sulfur, 4–50, on pre-pink, pink, etc.	100	0	100	Negligible.
10	Dry lime-sulfur, 3–50	96	4	98	Negligible.
11	Dry lime-sulfur, 3–50 (lead and lime-sulfur put on separately).	96	4	100	Negligible.
12	Check for plots 13 and 14 . . .	34	66	68	Negligible.
13	Sulfur dust	89	11	96	0
14	Copper-lime-arsenate dust . .	86	14	97	13

TABLE VII. — *Results on the Dusted Plots in Stowe and Marshall Orchards.*

STOWE ORCHARD.

Plot.	TREATMENT.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
12	Check for 25-year-old trees, sprayed with lead and nicotine only.	15	85	48	0
13	Sulfur dust, 25-year-old trees . .	74	26	92	0
14	Copper-lime-arsenate dust, 25-year-old trees.	87	13	97	21
12	Check for 12-year-old trees, sprayed with lead and nicotine only.	16	84	46	0
13	Sulfur dust, 12-year-old trees . .	83	17	96	0

MARSHALL ORCHARD.

Plot.	TREATMENT.	Clean Fruit (Per Cent).	Scab (Per Cent).	Marketable Fruit (Per Cent).	Russeted Fruit (Per Cent).
12	Check, sprayed with lead and nicotine only.	56	44	96	0
13	Sulfur dust	84	16	99	0
14	Copper-lime-arsenate dust . . .	93	7	100	26

MASSACHUSETTS

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PEDIGREE

THE BASIS OF SELECTING BREEDING MALES FOR EGG PRODUCTION

By F. A. HAYS and RUBY SANBORN

In this bulletin the records of ten years' poultry breeding investigations at the Massachusetts Agricultural Experiment Station are analyzed, specifically from the standpoint of the effect of the female ancestry on the transmitting power of the male. It is shown that the pedigree record basis of selection of the male has given marked results. On the other hand, there is nothing in the work done to date which in any way indicates superiority of this method over that of measuring transmitting power by means of the progeny test.

Available records, however, do indicate that the selection of females on the basis of those specific characters which together are believed to make up the group character of fecundity may be even more important in its results than the particular basis on which the male is selected.

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BULLETIN No. 215.

DEPARTMENT OF POULTRY HUSBANDRY.

PEDIGREE, THE BASIS OF SELECTING BREEDING MALES FOR EGG PRODUCTION.[1]

BY F. A. HAYS AND RUBY SANBORN.

Introduction.

The practical importance of the selection of breeding males in flocks bred for egg production is much appreciated by poultrymen. Some believe that the ability of hens to make good egg records is more largely traceable to their male ancestors than to their female ancestors. At any rate, the fact is well recognized that the male breeders must be carefully considered in developing a flock uniform for high production. Since actual egg production can be measured only by the females of the flock, other criteria must be employed in choosing the males. Some breeders prefer to use cockerels, while others make use of yearling or older cocks for breeding; but the merits or demerits of these practices will not be discussed in this paper. The following discussion of data available at the Massachusetts Experiment Station has a bearing on methods of selection that may be applied to both cockerels and cocks (Inherited Production), and other methods that apply only to cocks (Potential Production). Experimental evidence on the transmission of egg-producing ability through the male is in a confused state at present.

Pearl, '12, concludes, after studying the inheritance of egg production with several thousand Barred Plymouth Rocks representing thirteen generations: (p. 284) "That the record of egg production or fecundity of a hen is not of itself a criterion of any value whatsoever from which to predict the probable egg production of her female progeny. An analysis of the records of production of large numbers of birds shows beyond any possibility of doubt that, in general, there is no correlation between the egg production of individuals and either their ancestors or their progeny." Pearl draws the above conclusions because he found no significant biometric correlation between mothers and daughters or between daughters and their female ancestry in egg production. Pearl states, on the other hand, (p. 379), "High fecundity may be inherited by daughters from their sire, independent of the dam."

Goodale, '19, believes that egg production is transmitted equally through males and females in Rhode Island Reds. He further crossed Cornish males on Rhode Island Red females and secured winter egg production corresponding with that of his Rhode Island Red flock.

Lippincott, '20, in discussing the grading up of mongrel flocks by the use of standard-bred cockerels of three breeds, (p. 45), states that a pullet's egg produc-

[1] The data included in this bulletin were collected by Dr. H. D. Goodale, until recently in charge of poultry investigations at this Station. All Rhode Island Red fowls bred by the Experiment Station from 1912 to 1921 are included, with the following exceptions: a small number of birds in an experiment in studying the behavior of broodiness, and a small number of birds in an inbreeding experiment during the year 1921. The flock included in this report differs from that reported on in Bulletin No. 211 of this Station in that only fowls in the experiment entitled *Breeding for Egg Production* are reported in Bulletin No. 211.

tion seems to bear a closer relation to the breeding of her sire than to the production of her dam.

Dryden, '21, reporting on eight generations of Barred Rocks, eight generations of Leghorns and eight generations of Cross-breds, states that some hens and some males have the power of transmitting high fecundity; others have not this power. He advises the progeny test as the most reliable method of selecting breeders.

Hurst, '21, in his work in breeding White Leghorns and Wyandottes, found no sex linkage in the inheritance of factors for egg production. In other words, he agrees with Goodale and Dryden in his assumption that both parents contribute equally in factors for egg production.

Other authorities rather generally agree with one or the other of the above schools, so that it seems safe to assume that egg production is transmitted in Mendelian fashion from parent to offspring. A discussion of the several proposed genetic theories is not within the province of this report. Whether or not factors for egg production are transmitted in the same fashion in all breeds requires further study. This report is intended to throw some light on the expected progress in mass breeding without considering definite Mendelian factors as operating to control the egg production of the flock.

Review of Progress in the Flock.

The data upon which this report is based cover ten years' work at the Massachusetts Agricultural Experiment Station in breeding Rhode Island Red fowls primarily for egg production. The foundation flock of 100 pullets and eggs from which 50 more were hatched were purchased in the fall of 1912 from a Massachusetts breeder. These were good representatives of the breed, judged by the breed standards of that time. This foundation female stock was placed in the laying houses December, 1912, and all females in the experiment have since been trap-nested at all times unless physically incapacitated. All annual records cover 365 days and were made during the pullet year. Complete pedigrees of all breeding stock have been maintained throughout the period. The foundation males used consisted of twelve birds brought in in the spring of 1913, four from different breeders brought in in 1914, and ten from other outside sources brought in in 1915. Since 1915 no outside stock has been used in the flock.

Dr. Goodale has already given the question of egg production much study and made several reports on the egg-laying flock up to the end of the laying year 1921. His reports include a rather complete study on early maturity, rate and winter pause (Goodale, '18, '19). He has also carefully investigated the question of broodiness (Goodale, '20). This paper deals only with the application of methods for selecting breeding males, from data secured up to the end of 1922.

The average production of the flock by years is presented graphically in Chart I. All pullets that had an opportunity to lay for 364 days after their first egg are included. The birds are divided into six classes for study, and the percentage in each class is presented by years to show the general trend of the flock.

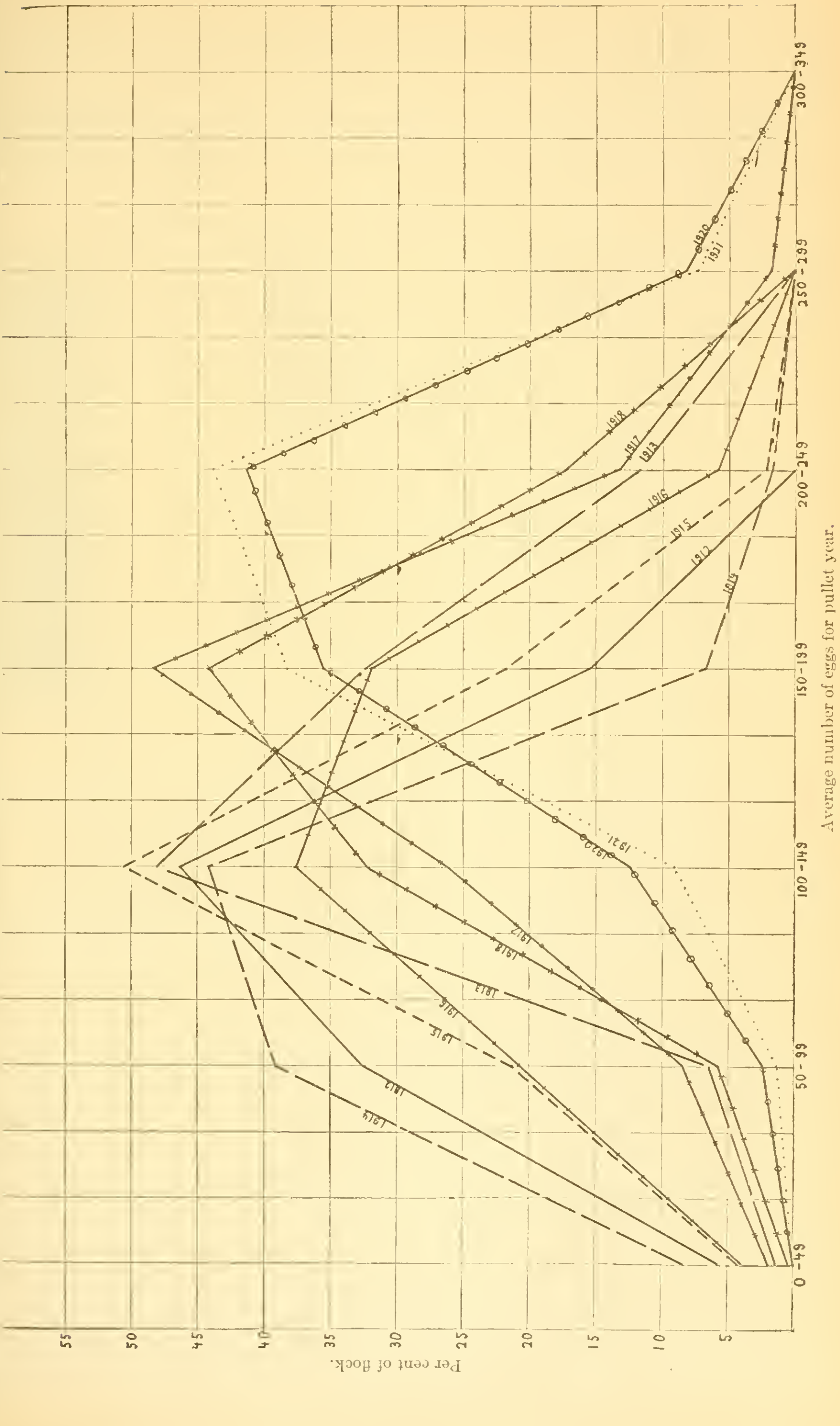
The total number of annual records at the close of 1922 was 1,945. The observation may be made that the mode (most common class) of the foundation stock lies between 100 and 149. Chart I further shows that the mode of the flock remained between 100 and 149 eggs until the 1917 pullets finished their year in the fall of 1918. This fact does not signify a lack of progress in increasing the egg production of the flock between 1913 and 1918. There was a total increase during this period up to the end of the laying year ending in 1918 amounting to an average of 12.97 eggs per hen. The graph for the hatching year 1913 would seem to indicate a higher degree of production in the flock as a whole than could be maintained in the flocks hatched in 1914 and 1915. This is only an apparent discrepancy, however, as explained by the fact that only about half the available flock hatched in 1913 could be trap-nested to the end of their laying year. The half selected represented those having the highest record for the first half of their year and consequently are a select group.

The distribution of the flock will be seen to remain almost the same for the birds

CHART 1.

FREQUENCY DISTRIBUTION IN EGG PRODUCTION.

Flock denoted by the year in which its annual egg-laying record commenced.

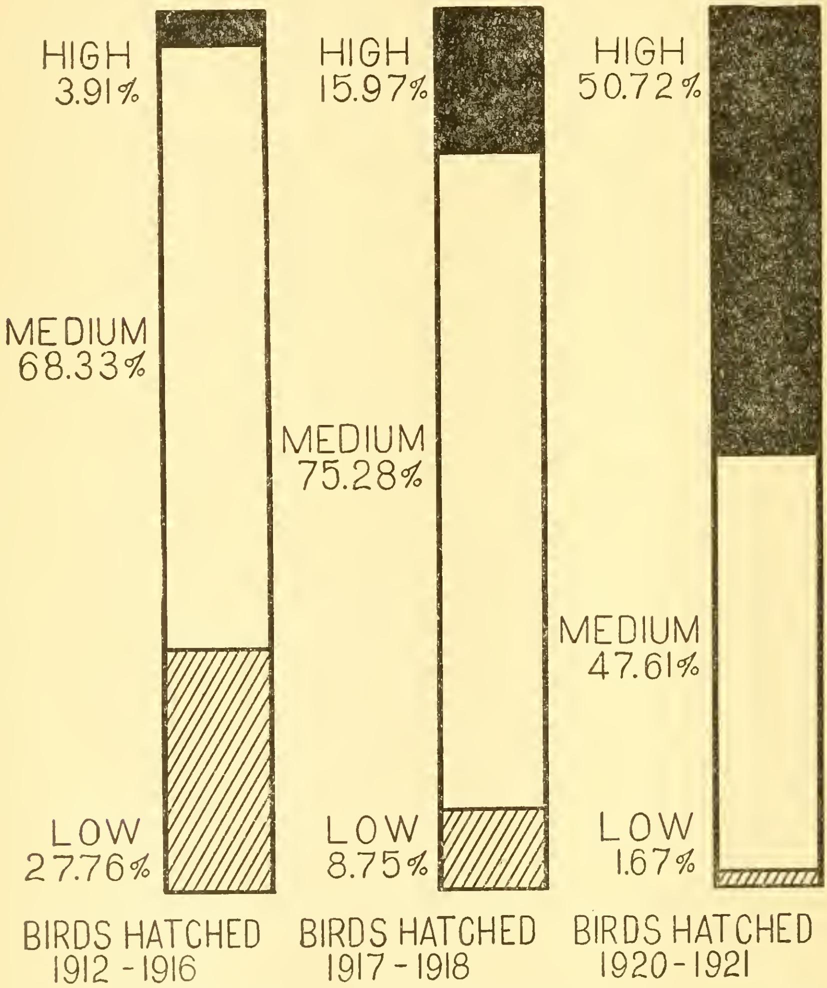


hatched in 1917 and 1918. Records for the flock hatched in 1919 were cut short by disease outbreaks. It was found necessary to dispose of most of the stock and exercise rigid quarantine measures. This prevented the completion of any annual records during 1920.

Referring again to Chart I, the mode of the flock will be observed to have advanced in 1920 to the 200 to 249 egg class, with a skewness indicating that the mode of the flock lies considerably above the average. In other words, a bimodal condition begins to present itself.

CHART II.

General Classification of Birds on the Basis of Production.



The results of the season ending in 1922 indicate that the general distribution of the 1921 flock conforms closely with that of 1920. The graph for 1921 also shows a bimodal condition of the flock, lying in the 150 to 199 class and in the 200 to 249 class.

Chart II is presented as supplementary to Chart I. Chart I shows that the most common group of producers falls in the 100 to 149 egg class in the years 1912 to

1916 inclusive; in the 150 to 199 egg class in the years 1917 and 1918; and in the 200 to 249 egg class in the years 1920 and 1921. Hence in the preparation of Chart II the birds hatched during the first five years have been grouped into one polygon, those hatched in the next two years into a second polygon, and those hatched in the last two years into a third polygon. Low producers laid from 0 to 99 eggs in their pullet year; medium producers laid from 100 to 199 eggs in their pullet year, high producers laid over 200 eggs in their pullet year.

Chart II shows that in the first five years there were 27.76 per cent low producers, 68.33 per cent medium producers and 3.91 per cent high producers. During the two-year period following, the percentage of low producers fell to 8.75, the medium class increased to 75.28 per cent, and the high producers increased to 15.97 per cent. During the last two years, the low class fell to 1.67 per cent, the medium class fell to 47.61 per cent, and the high class increased to 50.72 per cent.

Table 1, presented below, gives the number of sires used, the number of dams used, the number of pullets completing yearly records, and the average of all annual records by breeding years. The last column includes pullets hatched in the respective mating years.

TABLE 1.

Mating Year.	Number of Sires used.	Number of Dams used.	Number of Pullets with Yearly Records from Mating.	Average Annual Production of Pullets.
1913	12	42	77	146.22
1914	20	55	120	102.33
1915	21	99	378	122.93
1916	18	59	426	131.87
1917	14	52	318	159.19
1918	14	71	208	160.24
1919	12	29	None	None
1920	16	36	121	196.95
1921	9	43	297	197.89

Referring to the first column of the table, it will be observed that during the first four years of the experiment the average number of males was about 18, while during the past five years the number was cut down to an average of about 13. This policy has given a greater opportunity to determine the breeding ability of the sires and to regulate future mating with a greater degree of certainty, because the breeding ability of the sires can be ascertained with a higher degree of accuracy when their progeny are trap-nested in large numbers. This fact made it possible to regulate matings more carefully along specific blood lines.

The number of dams used was greater during the first four years of the experiment than during the last five. The range in number of dams for the nine-year period is from 29 to 99. The use of fewer dams makes possible more rigid selection standards and probably is of value in reducing variability in the flock.

The average number of completed records per year is 243. In general, the mean annual production of the flock shows progress from year to year. The first results of breeding at the Station are shown opposite the mating year 1913. Seventy-seven pullets averaged 146 eggs. These 77 pullets represent a selected group from a larger number, and consequently show a higher average than the 120 pullets hatched in 1914. The offspring of 1915 brings the average of the flock up to 123 eggs, and from that time to the present there has been uninterrupted progress, except for the disease outbreak of 1920. The 121 pullets hatched in 1920 averaged 197 eggs. The 297 hatched in 1921 averaged approximately 198 eggs. There is no noticeable tendency in the flock to produce a few phenomenal records, but rather a general homogeneity in production. This tendency to uniformity is probably traceable to the methods of mating for specific characteristics, and to a certain degree of relationship within the flock.

Selecting Breeding Males on Production Pedigree.

Before proceeding further with this question, it is necessary to define a few terms that are used in this report. *Sire's inherited production* is calculated from the average annual egg records of the 31 dams in five ancestral generations of each sire. *Dam's inherited production* is calculated from the average annual egg production of the 31 dams in five ancestral generations of each dam. *Sire's potential production* is the average of the annual records of all his daughters made during their first laying year. It is the same as daughter's annual production, save in those cases where a sire was used for more than one year.

It is a common practice to select males for breeding that come from dams with high annual egg records. In some flocks the practice is to emphasize the egg records of as many of the dams back of the sire as possible. In such cases the annual egg record is used as the guide for selection in a large measure, rather than any specific characters that the individual and his relatives may possess.

Table 2.

Mating Year.	Sires' Inherited Production.	Sires' Potential Production.	Dams' Inherited Production.	Daughters' Average Production.
1913	Unknown	136.55	Unknown	146.22
1914	138.00	107.29	117.07	102.33
1915	152.35	123.05	125.49	122.93
1916	149.93	133.23	144.63	131.87
1917	156.49	160.31	153.16	159.19
1918	156.77	161.23	151.78	160.24
1919	167.13	Not recorded	158.02	Not recorded
1920	168.79	196.95	163.02	196.95
1921	174.47	197.89	173.67	197.89

The inherited production of the sires used for the mating years included in this report is given in Table 2. This inherited production amounted to an average of 138 eggs in 1914, 152.35 in 1915, 149.93 in 1916, and so on up to an average of 174.47 in 1921, showing that although untested males from the progeny standpoint were used, those in charge were able to select a superior class of males each year, based on average annual records and pedigree. The progress that has been made in the flock as a whole would seem to indicate that this is a commendable practice. Such a method can be followed by breeders who keep complete pedigree and trap-nest records of their flock. Breeding sires from such flocks should command a high figure and should be very much appreciated by all smaller breeders who are seeking to improve their flocks without the use of the trap-nest or pedigree system. This method would be especially useful for selecting the more desirable cockerels to be retained. Mature sires can be selected with a greater degree of certainty from their progeny test.

Relative Importance of Sire's and Dam's Pedigree.

A great deal of discussion and difference of opinion exists as to the relative importance of the sire and the dam in breeding for egg production. Poultry investigators differ in their opinion on this point, some holding that sex linkage makes the sire of greater importance than the dam, while others hold that sire and dam are of equal importance. In Chart III the average inherited production of the dams for each year is given as a dash line. A similar figure for the sire is given as a solid line. The actual annual production of the daughters coming from the mating of these sires and dams on their respective years is given as a dotted line. It should be understood that the egg record of the daughters was finished the year following the hatching year. These graphs are fitted to a straight line by the ordinary method of least squares.

Chart III very clearly indicates that selection on a mass basis from egg records alone will not be an insurance as to what the daughters will do during their first egg-laying year. Reference to the chart shows that the annual production of the daughters crossed the path of the inherited annual production of the dams during the year 1916, and the path of the inherited production of the sires during 1917. *The average annual record of the daughters has far outstripped their inherited production from sires and dams.* These facts are unmistakable evidence of the operation of many factors to influence annual egg production. From the year 1916 this flock was bred for specific characteristics, such as early maturity, lack of broodiness and lack of winter pause. Those hens which showed later maturity, broodiness, and a tendency to stop laying during the winter season were discriminated against as breeders, even though they had made good annual records. Another characteristic which was sought was intensity of production. Those females that showed intense winter production were favored as breeders over others in which the degree of intensity was less marked.

CHART III.

RELATION BETWEEN PARENTS' INHERITED AND DAUGHTERS' AVERAGE PRODUCTION.

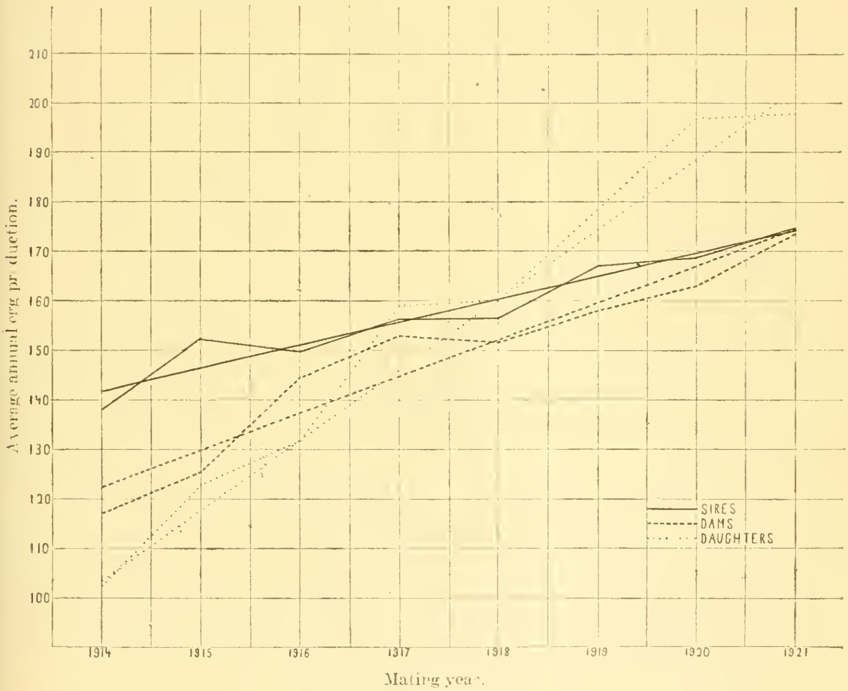


Chart III does not furnish any conclusive indication of the relative importance of sire and dam in transmitting annual egg production. This may be due to the fact that the chart is based on mass data. A similar chart based on specific families or blood lines would be more enlightening on this point. Data are available and will be published later. The one outstanding item to be emphasized on the chart is the advisability of selecting for specific characteristics as affecting annual egg yield.

The Sire's Potential Production as a Guide in Selecting Males.

The average annual egg production of the daughters of a sire we have called his potential production. In other words, in order to know the potential breeding ability of a sire, there must be a trap-nest record of his daughters. This fact greatly reduces the usefulness of the method with many poultrymen. Records at this Station indicate very clearly, however, that males vary widely in their ability to sire daughters that make high annual records. If it were possible to recognize such sires in advance, their usefulness in the flock could be made many fold greater. Referring back to Table 2: the column giving the sires' potential production is very similar to the average egg yield of the daughters for the respective years. It differs only in those cases where some of the sires were used for more than one breeding year. A comparison of this column with the one headed *Sires' Inherited Production* shows that in the early years the inherited production was higher than the potential production, but beginning in 1917 the reverse is the case; clearly indicating that the flock had been developed by the method of breeding to a higher degree of prepotency. This greater prepotency in the last four or five years is due to the fact that the flock has increased in the percentage of early maturing birds, in the percentage of birds that do not show the winter pause, in the percentage that are free from broodiness, and in the annual rate of production. As evidence of this fact, there are now families (all the daughters of a hen) that are non-broody. Other families show no winter pause, others show a uniformly higher rate, etc. There is still a wide range in the annual egg production of the females in the flock. This range may be explained on the Mendelian basis as we have shown elsewhere. The statement still holds good that there is no guide in selecting the sire that is as certain and reliable as the progeny test or the potential production.

How to Select Cockerels.

A great many poultrymen use cockerels to a considerable extent in their breeding operations; and even where cockerels are used only to a minor degree for breeding purposes the first year, it is necessary to select and reserve considerable numbers for future sires. Any guide in the selection of cockerels, then, has a double value to poultrymen.

We have previously shown that the average annual records of the hens in the dam's pedigree is of about the same value as the average annual record of the hens in the sire's pedigree, so far as determining what the daughters from such matings will produce is concerned. Selection of cockerels on their mothers' annual records alone is a very inefficient and inaccurate method, compared with the five-generation pedigree method we have used here. In our opinion, therefore, there is no other method of choosing the cockerels to be used in breeding for egg production that is as satisfactory as the combined sires' inherited production and dams' inherited production behind such cockerels.

How to Select Cocks.

Too much stress cannot be laid upon the importance of making full use of breeding males that have a demonstrated ability to sire heavy egg layers. The history of a good many flocks shows that the great producing hens from the flock trace directly to a very few outstanding males. The same principle holds here as in breeding the higher domestic animals. Sires of proven ability are invaluable.

The cock may be selected both on the pedigree basis and on the progeny test. The yearling cock will have daughters that have a winter record rather well along by his second mating season, if he has been used as a cockerel. Winter records are known to be of great value as guides to annual records. Therefore, the yearling cock can be selected with a good deal of certainty as to what contribution he will make to the flock. As a two-year-old, he will be a strictly tested individual; and if possessing the proper amount of vigor, and if properly handled, can be used very successfully for two or more mating seasons. The items which are the guides to follow in selecting the cock may be summed up as follows:

1. Select those with a high inherited production, both on the sire and the dam side, for as many generations as possible.
2. Select those that have the best progeny performance.
3. Select those whose family are early maturers, free from broodiness, free from a tendency to winter pause, and show a high rate of production.

Summary.

1. In the space of nine years selection of breeding males, largely on an inherited production basis, has assisted in raising the average annual egg production during the pullet year from 146 eggs to 198 eggs per hen.
2. Evidence as presented in this report has no bearing on the value of the progeny test as a guide in the selection of breeding males.
3. Selection of males for production of daughters possessing specific characteristics, such as early maturity, lack of winter pause, high rate of production and freedom from broodiness, is necessary to attain high egg yields.

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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

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DIGESTION EXPERIMENTS WITH CATTLE FEEDS

By J. B. LINDSEY, C. L. BEALS, P. H. SMITH, and J. G. ARCHIBALD

This bulletin reports results of digestibility studies on fourteen different materials, of real or claimed value as cattle feeds. The work of which this is a part was commenced thirty years ago. Results have been published in a number of reports and bulletins, and most of them summarized very briefly in a "Compilation of Analyses" published in November, 1919. Nearly all of the feed products available to Massachusetts dairymen have now been studied, and the digestibility of the nutrients contained measured. The publication of this bulletin, therefore, completes this phase of the service of the Massachusetts Experiment Station.

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

BULLETIN No. 216.

DEPARTMENT OF CHEMISTRY.

DIGESTION EXPERIMENTS WITH CATTLE FEEDS.

BY J. B. LINDSEY, C. L. BEALS, P. H. SMITH AND J. G. ARCHIBALD.[1]

Introduction.

The digestion experiments here reported cover a period of four years, the work commencing annually about November 1 and extending through to mid-April or thereabouts. Methods followed in conducting the tests are given elsewhere.[2]

Each digestion period extended over sixteen days, nine of which were preliminary (five in ordinary pens and four in the digestion stall), the last seven constituting the actual trial during which the feces were collected. The animals were grade sheep, as nearly as possible of the same age and weight. The basal ration was either English hay, or English hay and gluten feed. Ten grams of salt were fed daily and water *ad libitum.*

Discussion of Results.

A summary of the coefficients of digestibility is here presented, together with a brief discussion of the same.

English Hay.

Lot.	Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
1[3]	XXIII	1	9	57.90	45.16	47.35	61.90	59.67	43.90
1	XXIII	1	11	58.89	45.57	48.27	63.43	60.29	46.98
Average				58.40	45.37	47.81	62.67	59.98	45.44
2	XXIII	10	9	57.83	35.84	47.56	66.16	56.61	36.45
2	XXIII	10	11	60.59	41.43	53.47	67.73	59.40	40.35
2	XXIII	11	15	57.22	47.88	46.89	64.05	55.78	30.54
2	XXIII	11	17	56.76	46.81	45.44	64.38	55.15	24.83
2	XXIII	13	12	58.78	43.20	46.66	64.42	59.77	20.28
2	XXIII	13	13	60.68	28.11	49.25	67.97	61.43	23.22
2	XXIV	10	15	50.71	32.05	43.48	59.24	48.08	33.91
2	XXIV	10	16	53.30	20.57	39.43	63.65	51.12	38.53
Average				56.98	36.99	46.52	64.70	55.92	31.01

[1] Mr. Beals had immediate supervision of the experiments and did some of the analytical work. Mr. Smith, assisted by Miss E. M. Bradley, did the larger part of the analytical work. The tabulations were made by Mr. Archibald. The work at the feeding barn was done by Mr. J. R. Alcock.

[2] Mass. Agr. Expt. Sta., 11th Ann. Rpt., pp. 146–149, 1893.

[3] This lot of hay is the same as was fed in Series XXII, periods 8–17, coefficients of which are published in Mass. Agr. Expt. Sta. Bul. 181, p. 307.

English Hay — Concluded.

Lot.	Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
3	XXV	2	12	59.20	24.26	55.74	64.33	61.22	46.83
3	XXV	2	13	56.77	20.53	49.81	64.67	57.75	43.65
3	XXV	3	9	64.07	39.80	57.06	69.98	65.04	44.97
3	XXV	3	11	61.42	34.17	57.13	67.29	62.48	38.96
3	XXV	9	15	59.41	39.01	58.85	63.21	59.97	50.67
3	XXV	9	16	60.03	37.19	55.28	65.37	60.83	47.57
3	XXVI	1	17	59.95	29.40	54.92	65.68	61.19	46.97
3	XXVI	1	18	64.17	40.54	61.14	68.41	65.29	50.83
3	XXVI	1	19	59.89	34.96	55.22	63.78	61.73	45.76
Average				60.55	33.32	56.13	65.86	61.72	46.25
General average of above				58.82	36.13	51.21	65.03	59.09	39.75
General average, 5 earlier lots . . .				59.47	36.31	49.78	64.10	62.35	46.34
Timothy hay, for comparison . . .				55.00	39.00	47.00	51.00	62.00	50.00

Note. — Each series represents one winter's work, commencing about November 1 of each year and extending through to mid-April or thereabouts.

Three separate lots of hay were used in these experiments. It was of quite uniform quality and composition and consisted of mixed grasses, largely Kentucky blue grass, sweet vernal grass and some clover. It averaged in percentage of dry matter, 6.07 ash, 7.95 protein, 33.81 fiber, 49.52 nitrogen-free extract, and 2.65 fat. Such hay is rather richer in protein and has a higher degree of digestibility than has average timothy hay. The digestion results are on the whole quite uniform. It is interesting in this connection to compare the general average of the present results with the average of five earlier lots here cited and originally reported in Bulletin 181 of this Station. The close agreement of the two sets of coefficients in all items except fat emphasizes the fact that, when any considerable number of results are averaged, the resultant average is a pretty close approximation to accuracy and an accepted standard, even though there be considerable variation among the individual data.

English Hay and Gluten Feed — Basal.

Lot.		Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Hay.	Gluten Feed.									
2	1	XXIV	1	9	63.70	32.02	62.98	65.43	66.74	48.22
2	1	XXIV	1	11	67.31	40.75	69.24	68.37	69.51	54.82
2	1	XXIV	14	12	65.09	46.22	66.29	66.95	66.58	41.34
2	1	XXIV	14	13	65.56	45.61	67.57	66.77	67.28	43.39
3	2	XXV	1	9	64.81	29.53	69.27	66.40	67.34	54.79
3	2	XXV	1	11	67.89	30.57	71.20	70.67	70.42	56.32
3	2	XXV	4	12	66.72	27.44	71.59	67.20	69.63	55.02
3	2	XXV	4	13	66.62	20.55	73.19	67.66	69.48	54.30
3	2	XXV	6	15	67.68	27.40	72.71	67.58	70.88	55.92
3	2	XXV	6	16	65.92	20.94	70.34	66.14	69.44	55.55
3	2	XXVI	3	17	64.88	23.73	68.85	66.81	68.21	44.94
3	2	XXVI	3	18	65.46	23.16	65.11	72.39	67.01	46.96
3	2	XXVI	3	19	64.79	28.18	70.91	66.69	66.92	48.48

Note. — In all of these trials with the exception of period 3, Series XXVI, the ration fed was *500* grams of hay and 150 grams of gluten feed. In the exception noted, the ration was *550* grams of hay and 150 grams of gluten feed. Because of this difference in the ration fed, these results are not averaged.

Experience has proved that gluten feed is a satisfactory supplement to hay for use in basal rations. The necessity for such a supplement is greatest when the material under test is deficient in protein or is of a coarse, fibrous, unpalatable nature.

Gluten Feed.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	1	9[1]	79.37	negative	73.56	37.80	89.76	70.95
XXIV	1	11	94.97	54.09	85.35	92.46	99.83	92.21
XXIV	14	12	82.09	123.50	82.51	83.85	83.86	77.25
XXIV	14	13	84.12	118.34	84.93	80.66	86.40	83.11
XXV	1	9[1]	70.86	negative	81.24	26.30	77.02	87.85
XXV	1	11	84.26	negative	85.05	96.50	89.06	93.31
XXV	4	12	95.72	56.84	89.86	102.10	100.55	84.34
XXV	4	13	95.28	12.76	93.03	109.94	99.95	81.53
XXV	6	15[1]	93.23	negative	88.09	125.06	101.97	76.91
XXV	6	16	85.60	negative	83.41	100.55	96.40	75.42
XXVI	3	17	79.23	negative	81.70	82.49	84.62	29.55
XXVI	3	18[1]	93.37	negative	79.99	281.89	88.37	38.32
XXVI	3	19	78.83	negative	86.21	80.19	79.27	50.86
Average			86.68	–	85.78	92.08	91.10	74.18
Average all previous trials			91.08	–	86.11	124.21	93.56	72.38

[1] Not included in the average.

The average composition and limits of variation of the two lots of gluten feed used in these experiments were as follows: dry matter 90 per cent (87.80–91.22), made up of ash 3.35 (2.52–4.74), protein 27.56 (24.53–29.50), fiber 6.83 (6.31–7.31), nitrogen-free extract 59.16 (56.44–62.52), fat 3.11 (2.08–4.31). The digestion coefficients for gluten feed were secured by applying the coefficients obtained for hay to the amount of hay fed, and deducting the product from the total digestible matter of the basal ration.

The negative results for ash in a majority of the trials are almost always noticed in work with gluten feed. No satisfactory explanation for such results can be given although they may be attributed in part to experimental error due to the small amount of ash present, and in part to the excretion of digested mineral matter from the intestines. In the case of fiber, it will be noticed that occasionally the coefficients were above 100 per cent, due probably to improvement in digestibility of the fiber in the hay as the result of adding a protein concentrate.

Incidentally it may be remarked that as a result of five separate trials with corn bran, the fiber was found to have an average digestibility of 75.12 per cent. This, together with the results secured for the fiber in gluten feed, shows that the fiber in corn is quite well utilized.

The present data, as well as those obtained as a result of many previous trials, show gluten feed to be a highly digestible protein concentrate.

Dried Apple Pomace.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXVI	4	9	63.48	negative	negative	71.41	73.88	28.35
XXVI	4	11	68.11	56.25	negative	72.93	75.78	40.33
XXVI	5	17	71.41	2.53	negative	87.08	79.01	43.85
XXVI	5	19	59.45	14.01	negative	60.98	71.03	36.10
Average			65.61	–	–	73.10	74.93	37.16
XXVI	6	9	77.02	94.03	negative	80.21	83.87	37.14
XXVI	6	11	65.49	53.84	negative	58.61	75.45	25.22
XXVI	8	19	71.82	107.14	negative	52.13	73.39	41.38
Average			71.44	84.67	–	63.65	77.57	34.58
Average present trials			68.11	–	–	69.05	76.06	36.05
Average previous trials (6)			71.50	48.70	–	64.40	84.40	45.30
Dried beet pulp, for comparison			75.00	26.00	52.00	83.00	83.00	–

Note. — In periods 4 and 5 the pomace was fed unground. In periods 6 and 8 it was fed in the finely ground state. Two sheep were started in period 8, but one became sick and had to be rejected. The previous trials, averages of which are reported here for comparison, were with wet pomace.

This material was studied quite extensively during the winter of 1920–21, with respect to chemical composition, digestibility and value for milk production, and the results published in Bulletin 205. It is a carbohydrate feed, having a negligible amount of ash and relatively little protein. An average of the analyses of six samples shows a dry matter content of 94.70 per cent, composed of ash 1.55, protein 5.88, fiber 19.22, nitrogen-free extract 68.64, and fat 4.71.

The results of seven single digestion trials show a fairly high degree of digestibility as regards total dry matter, ash, fiber and nitrogen-free extract. The fat is rather poorly digested, due doubtless to the fact that it is not true fat but waxy material; and the protein is apparently not digested at all, or because of the small amount present the coefficients are of uncertain value. Dried beet pulp, a somewhat similar type of feed, has a slightly higher digestibility.

Barley Screenings.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIII	12	9	54.31	15.22	65.12	34.25	60.29	9.96
XXIII	12	11	60.59	29.79	82.72	42.65	63.99	8.99
Average			57.45	22.51	73.92	38.45	62.14	9.48
Oat feed, for comparison			52.00	47.00	86.00	49.00	47.00	58.00

Barley screenings is the residue from barley flour, which was prepared in considerable amounts during the war period. It contained dry matter 89.73 per cent, which was composed of ash 6.30, protein 9.98, fiber 19.51, nitrogen-free extract 61.08, fat 3.13.

Except for its lower fiber content, it resembled both oat feed and hay in chemical composition. Its total dry matter is a little better digested than oat feed because of a less complete separation of the starchy matter, and it has approximately 5 per cent greater feeding value.

Carrots.

(*a*) *Carrots fed with Hay.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIII . . .	4	12[1]	97.56	28.42	80.22	165.87	103.91	106.48
XXIII . . .	4	13	74.34	10.15	65.19	54.28	89.23	75.14
XXIII . . .	5	12	76.95	6.21	67.84	72.24	92.86	60.91
XXIII . . .	5	13	80.65	18.88	83.16	67.97	94.38	66.82
Average present trials			77.31	11.75	72.06	64.83	92.16	67.62
Average 5 previous trials			85.90	47.75	75.90	102.14	93.51	41.33

(*b*) *Carrots fed with Hay and Gluten Feed.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	9	9	78.50	49.64	56.78	80.27	87.82	6.06
XXIV	9	11	82.27	41.27	62.18	91.95	91.94	18.79
XXIV	11	9	85.88	50.17	55.80	140.63	93.31	36.58
XXIV	11	11	74.59	30.68	50.85	108.23	85.31	5.69
Average present trials			80.31	42.94	56.40	105.27	89.60	16.78
Average all trials (7 present, 5 previous) .			81.89	37.15	68.44	93.86	91.87	39.72

[1] Not included in the average.

The digestion work with carrots is a continuation of earlier work reported in Bulletin 181. In the present trials, two lots of carrots were fed, averaging 88.02 per cent water, with dry matter composed of ash 9.91, protein 8.92, fiber 8.33, nitrogen-free extract 71.61, fat 1.23. In common with most other roots, they are relatively low in protein, fiber and fat, and high in ash and nitrogen-free extract.

The first lot (periods 4 and 5, Series XXIII) was fed with hay only; the second lot (periods 9 and 11, Series XXIV) was fed with hay and gluten feed; and in both cases constituted about 20 per cent of the dry matter of the ration.

The digestibility of the dry matter of the carrots in the present hay-carrot ration was 77 per cent as against 86 per cent in five previous trials. In both experiments quite wide variations are observed for which a satisfactory explanation cannot be given. It is quite possible that bacterial activity in the intestinal tract was more pronounced in some cases than in others.

When the carrots were fed in combination with hay and gluten feed, their digestibility appeared to be slightly more — 80 per cent as against 77 per cent when fed with hay only.

The fiber in carrots as well as in most roots appears to be quite completely digested, former experiments with mangels and turnips showing a dry matter digestibility of 87 to 89 per cent. The carrots seem to fall slightly below these figures.

Coffee Refuse.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	14	15	26.95	97.18	11.48	12.76	32.03	75.36

This material was the residue from the coffee bean, and was being used as a component of a low-grade feed mixture. It contained 93.77 per cent of dry matter, which was composed of ash 5.29, protein 13.29, fiber 33.86, nitrogen-free extract 40.98 and fat 6.58. It was fed in combination with hay and gluten feed to the extent of about 16 per cent of the dry matter of the ration. One sheep refused the mixture, while the other ate it but digested only a small portion. It evidently had very little nutritive value.

Cottonseed Meal.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	15	12	75.03	95.44	82.57	33.43	82.67	102.75
XXV	15	13	69.54	72.45	81.80	13.35	78.75	93.31
Average			72.29	83.95	82.19	23.39	80.71	98.03
Average all previous trials (14) . . .			79.00	65.00	84.00	32.00	77.00	95.00

The sample contained 92.90 per cent of dry matter, which had 7.40 per cent of ash, 39.35 per cent of protein, and 20.05 per cent of fiber, the latter ingredient being some 8 per cent above the average. It is evident that considerable ground hulls had been added, and the above coefficients show that such an admixture caused the digestibility to be below that for the better grades. As is well known, cottonseed meal is sold on a basis of from 43 to 36 per cent protein; the latter grade results from the addition of ground hulls, which naturally reduces both its feeding and fertilizing value.

Feterita.

Series.	Period.	Sheep.	Dry. Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXVI	10	17	86.71	188.88	86.77	negative	89.73	90.57
XXVI	10	19	86.59	123.08	98.55	negative	89.63	88.61
Average			86.65	155.98	92.66	–	89.68	89.59
Average previous trials (2)			74.65	–	46.55	–	87.94	56.69
Texas Station results[1]			88.99	–	90.03	50.00	96.60	74.52
Corn, for comparison			90.00	–	74.00	57.00	94.00	93.00

[1] Texas Agr. Expt. Sta. Bul. No. 203, p. 32.

Feterita or sudan durra is one of the grain sorghums which include also milo, durra and kaoliang. Two digestion trials were made on another sample a number of years since and reported in Bulletin 181. The present sample analyzed 89.22 per cent of dry matter, which contained ash 1.75, protein 14.46, fiber 1.63, nitrogen-free extract 78.37, and fat 3.8 per cent. In chemical composition it resembles Indian corn, except for its higher protein and lower fat percentage. The present digestion coefficients are quite uniform, and conform fairly well to those secured at the Texas Station. It is evident that feterita is about equal to corn in digestibility. The results secured by us in the former trial, showing 75 per cent of dry matter, 51 per cent of protein and 61 per cent of fat digested, were evidently too low, although they were obtained under satisfactory experimental conditions.

Oat Feed.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	12	12	51.30	92.67	81.48	39.03	44.88	118.62
XXIV	12	13[1]	18.94	52.47	4.85	0.83	19.47	101.80
XXV	11	9[1]	28.71	negative	18.28	22.57	30.74	184.69
XXV	11	11[1]	26.88	negative	22.23	20.93	32.20	99.69
XXV	13	9	54.89	25.70	85.57	55.59	49.38	43.28
XXV	13	11	51.46	25.70	89.90	42.79	49.04	46.23
XXV	18	12	56.68	68.79	89.63	57.12	52.37	15.96
XXV	18	13	46.51	23.07	85.95	52.55	39.61	66.57
Average			52.17	47.19	86.51	49.42	47.06	58.13
Timothy hay, for comparison			55.00	39.00	47.00	51.00	62.00	50.00

[1] Not included in the average.

Note. — The average coefficients for ash, fiber, nitrogen-free extract and fat in oat feed, published in Table II (e), p. 120 of Bulletin No. 200, are incorrect. The correct figures are given here.

The value of this material as a food for farm stock was studied by us some two years ago, and the results of the work have been published as Bulletin 200 of this Station. Oat feed, as the term is generally understood by the trade, is a by-product of oatmeal manufacture, and consists of the reground hulls plus the middlings and dust from the first milling of the grain. At some mills the residue from the second milling is also incorporated, but this is not the usual practice.

An average of the analyses of four samples shows the following percentage composition in dry matter: ash 6.48, protein 6.20, fiber 29.18, nitrogen-free extract 55.82, and fat 2.31. It resembles ordinary English hay in composition, except that it contains rather less fiber.

Eight single digestion trials were made with the sheep on this material, four in combination with hay (500 grams hay, 150 grams oat feed), and four with hay and gluten feed (500 grams hay, 150 grams gluten feed, 150 grams oat feed). The results of three of the trials were so much below the others in almost all respects that they are not included in the average. The average of the other five shows a digestibility comparable with timothy hay.

Oat Hulls.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIV	13	9	31.30	15.74	negative	49.64	28.94	negative
XXIV	13	11	36.23	9.46	12.10	51.45	36.13	14.38
Average			33.77	12.60	–	50.55	32.54	–

These coefficients have also been published in Bulletin 200.

The oat hulls contained the following percentages in dry matter: ash 6.37, protein 2.52, fiber 32.66, nitrogen-free extract 57.44, and fat 1.01. Fiber and nitrogen-free extract constitute the larger part of the hulls. The total dry matter is about one-third digestible, which places them among the lowest grades of cereal by-products.

Peanut By-Products.

A study has been made of three peanut by-products, viz., peanut meal, peanut shells and peanut skins. Peanut meal is the ground residue from the extraction of edible oil or soap oil stock. In the former instance it consists of the ground residue from the kernels only, and is specifically known as peanut oil meal. In the manufacture of soap-stock oil the whole peanut is extracted, and the ground residue should be known as peanut feed, a product much inferior to the peanut oil meal, due to the admixture of shell and skin. Peanut shells are the ground or unground outer hull of the nut; while peanut skins are the thin, waxy inner coat of the endosperm or kernel.

Analysis.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Peanut meal	92.33	5.27	39.74	5.09	33.67	16.21
Peanut shells	96.70	3.28	8.91	63.16	18.88	5.77
Peanut skins	94.59	3.46	18.75	8.48	40.01	29.29

Peanut meal, as indicated by the analysis, is a high-grade protein feed with considerably more fat than is contained in most concentrates. The shells are composed of nearly two-thirds fibrous material. The skins contain a reasonable amount of protein and nitrogen-free extract, comparatively little fiber, and a very high percentage of fat.

Coefficients of Digestibility.

(*a*) *Peanut Meal.*

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXV	19	9	74.62	negative	80.81	59.43	77.59	87.84
XXV	19	11	80.53	5.34	85.47	47.52	84.02	93.94
Average			77.58	–	83.14	53.48	80.81	90.89
German data[1]			83.00	–	90.00	(9)	84.00	90.00
(*b*) *Peanut Skins.*								
XXV	8	11	38.48	negative	49.49	negative	28.80	90.16
XXV	12	15	8.43	34.93	negative	negative	2.70	93.47
(*c*) *Peanut Shells.*								
XXV	16	9	32.83	34.24	69.35	8.63	29.25	83.32
XXV	16	11	25.19	12.61	67.72	.69	55.68	84.83
Average			29.01	23.43	68.54	–	42.47	83.58

[1] Mentzel & Lengerke Landw. Kalender 1922, results of seven single trials with four samples.

While the digestion results with peanut meal are not as high as the average results secured by German observers, the utilization of the protein, nitrogen-free extract and fat, of which it is largely composed, shows that the meal should be placed among the best of the protein feedstuffs.

The digestion results secured with the peanut skins are neither concordant nor very satisfactory. However, in each case they show that the fat, which comprises nearly 30 per cent of the skins, was quite fully utilized. When the skins were fed with hay (period 8), the digestion of the fiber of the ration seemed to be noticeably depressed or interfered with; and when fed with hay and gluten feed (period 12), none of the organic ingredients except the fat was digested. One might therefore conclude that the fat interfered with the utilization of the protein, fiber and nitrogen-free extract. On the basis of the above results, their value as a cattle feed is questionable. In order to utilize them economically, it may be possible to extract the oil and use the residue for litter or for packing purposes.

Peanut shells are shown to have a low digestibility, inferior even to oat hulls. While the small percentage of protein and fat which they contain seems to be well utilized, the fiber which comprises over 60 per cent of the dry matter apparently is little if any digested. The shells, therefore, are of little value as a feed.

Velvet Bean Feed.

Series.	Period.	Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
XXIII	8	12	82.06	41.48	76.64	81.07	89.71	86.69
XXIII	8	13	71.48	28.52	73.96	51.09	81.82	74.41
XXIII	9	9	70.96	22.97	68.56	46.60	80.35	72.79
XXIII	9	11	81.16	33.24	78.02	71.06	86.83	85.63
Average			76.42	31.55	74.29	62.46	84.68	79.88
Wheat bran, for comparison			66.00	–	77.00	39.00	71.00	63.00

Velvet bean feed consists of the ground seed and pod of the velvet bean, a rank-growing tropical legume which is cultivated extensively in Florida, Alabama and Mississippi. It has appeared at different times in Massachusetts, and a full report on its merits may be found in Bulletin 197.

Its composition on a dry matter basis is as follows: dry matter 88.16, ash 5.79, protein 18.94, fiber 14.50, nitrogen-free extract 56.16, fat 4.62. It resembles wheat bran in composition, but has slightly more protein and considerably more fiber, due to the presence of the pods. The average of the four trials shows about the same amount of digestible protein as is found in wheat bran. The fiber, nitrogen-free extract and fat are, however, somewhat more digestible, and on the basis of total digestible nutrients the velvet bean feed has about 11.5 per cent greater feeding value than bran.

Summary.

In the table following, the average composition of each feeding stuff is given, together with the average coefficients of digestibility and the limits of error, calculated by Bessel's formula. The error limit is large in some cases, the cause therefor being explained in the discussion of results on pages 53-61. In case of oat hulls and peanut shells the results vary so widely that the limits of error are not stated. The coefficients indicate that much difficulty was experienced in digesting these materials and that they possessed comparatively little nutritive value. The coefficients for the ash in all cases are of uncertain value because it is now recognized that a considerable portion of the digested mineral matter is excreted through the feces, whereas in case of organic nutrients the end products of digestion are eliminated through the lungs, skin and urine. Where the percentage of fat in the feed is small — 1 per cent or less — the coefficients have little meaning.

Composition and Coefficients of Digestibility of Feeding Stuffs.

Feedstuff.	Number of Tests.	Number of Animals.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
English Hay, composition	–	–	89.67	6.07	7.95	33.81	49.52	2.65
Coefficients, lot 1	2	2	58.40±0.33	45.37± 0.14	47.81±0.31	62.67±0.52	59.98±0.21	45.44
Coefficients, lot 2	8	7	56.98±0.82	36.99± 2.29	46.52±0.98	64.70±0.66	55.92±1.08	31.01± 1.79
Coefficients, lot 3	9	9	60.55±0.53	33.32± 1.60	56.13±0.70	65.86±0.51	61.72±0.53	46.25± 0.81
Average coefficients	19	9	58.82±0.49	36.13± 1.32	51.21±0.90	65.03±0.39	59.09±0.66	39.75± 1.42
Gluten Feed, composition	–	–	90.00	3.35	27.56	6.83	59.16	3.11
Coefficients	9	6	86.68±1.54	–	85.78±0.81	92.08±2.44	91.10±1.83	74.18± 4.68
Dried Apple Pomace, composition	–	–	94.70	1.55	5.88	19.22	68.64	4.71
Unground, coefficients	4	4	65.61±1.77	–	–	73.10±3.62	74.93±1.13	37.16±2.25
Ground, coefficients	3	3	71.44±2.25	–	–	63.65±5.73	77.57±2.16	34.58± 3.26
Both lots, coefficients	7	4	68.11±1.50	–	–	69.05±3.18	76.06±1.08	36.05± 1.76
Barley Screenings, composition	–	–	89.73	6.30	9.98	19.51	61.08	3.13
Coefficients	2	2	57.45±2.12	22.51± 4.91	73.92±5.94	38.45±2.83	62.14±1.25	9.48± 0.33
Carrots, composition	–	–	12.00	9.91	8.92	8.33	71.61	1.23
With hay, coefficients	3	2	77.31±1.23	11.75± 2.52	72.06±3.78	64.83±3.66	92.16±1.03	67.62± 2.79
With hay and gluten feed, coefficients	4	2	80.31±1.64	42.94± 3.08	56.40±1.57	105.27±8.84	89.60±1.24	16.78± 4.90
Coffee Refuse, composition	–	–	93.77	5.29	13.29	33.86	40.98	6.58
Coefficients	1	1	26.95	97.18	11.48	12.76	32.03	75.36
Cottonseed Meal, composition	–	–	92.90	7.40	39.35	20.05	25.33	7.87
Coefficients	2	2	72.29±1.85	83.95± 7.75	82.19±0.26	23.29±6.77	80.71±1.32	98.03± 3.18
Feterita, composition	–	–	89.22	1.75	14.46	1.63	78.37	3.80
Coefficients	2	2	86.65±0.04	155.98±22.19	92.66±3.97	–	89.63±0.03	89.59± 0.66
Oat Feed, composition	–	–	93.11	6.48	6.20	29.18	55.82	2.31
Coefficients	5	4	52.17±1.18	47.19± 9.59	86.51±1.04	49.42±2.43	47.06±1.49	58.13±11.56
Oat Hulls, composition	–	–	91.75	6.37	2.52	32.66	57.44	1.01
Coefficients	2	2	33.77	12.60	–	50.55	32.54	–
Peanut Meal, composition	–	–	92.33	5.27	39.74	5.09	33.67	16.21
Coefficients	2	2	77.58±1.99	–	83.14±1.57	53.48±4.02	80.81±2.17	90.89±2.06
Peanut Shells, composition	–	–	96.70	3.28	8.91	63.16	18.88	5.77
Coefficients	2	2	29.01	23.43	68.54	–	42.47	83.58
Velvet Bean Feed, composition	–	–	88.16	5.79	18.94	14.50	56.16	4.62
Coefficients	4	4	76.42±2.03	31.55± 2.64	74.29±1.41	62.46±5.51	84.68±1.47	79.88± 2.46

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THE VALUE OF BUTTERMILK AND LACTIC ACID IN PIG FEEDING

By J. B. LINDSEY and C. L. BEALS

Condensed (semi-solid) and dried buttermilk are by-products of the creamery industry, now widely advertised for use in pig feeding. An experiment with twelve growing pigs showed that condensed (semi-solid) and dried buttermilk when fed in limited amounts proved altogether too expensive to warrant their use for economical pork production. The semi-solid milk cost six cents and the dried article twelve cents a pound, and they were fed in the diluted form to the extent of from two to four quarts daily per pig.

Two experiments with lactic acid added to the grain slop in the amounts usually found in ordinary buttermilk showed no pronounced effect in promoting appetite or in causing an increase of growth.

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BULLETIN No. 217.

DEPARTMENT OF CHEMISTRY.

THE VALUE OF BUTTERMILK AND LACTIC ACID IN PIG FEEDING.

BY J. B. LINDSEY AND C. L. BEALS.

Condensed and Dried Buttermilk as a Food for Pigs.

Buttermilk, as it comes from the creamery, has long been recognized as a valuable food for growing pigs and poultry. Some thirty-five years ago, the late Professor Goessmann of this Station showed that on the basis of total solid ingredients (dry matter), buttermilk and skim milk when fed to growing pigs possessed substantially equal values.

At the present time neither by-product is obtainable in regular supply in most sections of Massachusetts at prices which warrant its use, especially for pigs. In recent years buttermilk, from which a portion of the water has been removed by the use of a partial vacuum and which is of a pasty consistency, has been placed upon the market under the trade name of semi-solid buttermilk,[1] and offered at from five and one-half to six cents per pound in barrel lots. It is also put up in fifty-pound wooden pails, intended particularly for poultry. A completely dried buttermilk, of a creamy color and of a powdered or flaky appearance, is also to be had, costing from ten to twelve cents a pound.

Inasmuch as the condensed or "semi-solid" material is freely advertised and its use recommended and urged, it seemed worth while to test its economy by feeding it in limited amounts to two groups of pigs. The dried buttermilk was also similarly tried.[2]

Chemical Composition.

Material.	Water.	Ash.	Protein.	Lactic Acid.	Milk Sugar.	Fat.
"Semi-solid" buttermilk	67.63	3.25	12.43	7.02	8.77	.90
"Semi-solid" buttermilk	67.06	–	–	–	–	–
Dried buttermilk	6.64	8.29	32.71	–	51.91[3]	.75
Liquid buttermilk	91.60	0.70	3.60	–	5.00[3]	.10–.27
Skim milk,[4] for comparison	90.10	0.70	3.80	–	5.20	.20

[1] The Universal Products Sales Co., 165 Liberty St., New York, are wholesale distributors.
[2] Sample secured from the Merrell-Soule Co., Syracuse, N. Y. The Collis Products Co., of Clinton, Iowa, claim to be large manufacturers of dried buttermilk and offer it in paper-lined sax at $9.50 a cwt. delivered, or $10 a cwt. in barrels. The price, naturally, is subject to change.
[3] Including lactic acid.
[4] Centrifugal process of separation.

The first two analyses represent the composition of the "semi-solid" material as it was received in barrels. It was about two-thirds water, whereas ordinary liquid buttermilk as it comes from the creamery contains about nine-tenths water. Naturally, the semi-solid milk contains more protein, ash, lactic acid, milk sugar and fat because of the evaporation of a part of the water. The dried buttermilk contained scarcely 7 per cent of water. On the basis of dry matter, 300 pounds of "semi-solid" buttermilk would be equal in feeding value to about 100 pounds of dried buttermilk; and on this basis should sell for four cents a pound when a like amount of the dried article was costing twelve cents. Actually, however, the cost of the "semi-solid" buttermilk was six cents a pound as compared to twelve for the dried buttermilk. Freight and cartage also favor the latter article, if either is to be bought.

Plan of Experiment.

Twelve pigs, weighing from 33 to 50 pounds each, were divided into six lots of two each (sow and barrow), and *each lot* was fed on a definite ration. An ash mixture was kept continuously before each lot, composed of:

20 per cent Salt.
40 per cent Rock phosphate.
20 per cent Ground limestone.
20 per cent Wood ashes.

The several lots were fed as follows:

Lot I. — Nine ounces of grain mixture I to each quart of warm water, in amounts to satisfy appetites.

Grain Mixture I.

20 pounds Ground oats.
40 pounds Flour middlings.
40 pounds Corn meal.

This was considered a check ration, and as good as could be made from purchased grain.

Lot II. — Nine ounces of grain mixture II to each quart of warm water, in amounts to satisfy appetites.

Grain Mixture II.

90 pounds Grain Mixture I.
10 pounds Digester or pig tankage.

This was an improvement over the ration fed to Lot I in that it contained 10 per cent of high grade tankage testing 19.9 per cent of ash and 63 per cent of protein. It also could be considered a check ration.

Lot III. — Four quarts of diluted "semi-solid" buttermilk daily, plus nine ounces of grain mixture I to each quart of warm water in amounts to satisfy appetites. The buttermilk in all cases was diluted to the consistency of ordinary buttermilk.

Lot IV. — Eight quarts of diluted "semi-solid" buttermilk daily, plus the same grain ration fed to Lot III.

Lot V. — Twelve ounces of dried buttermilk stirred into four quarts of warm water daily, plus the same grain ration fed to Lot III.[1]

Lot VI. — Twenty-four ounces of dried buttermilk stirred into eight quarts of warm water daily, plus the same grain ration as fed to Lot III.

After the animals had reached about 100 pounds each in weight, the grain mixture received by Lot II was changed by reducing the tankage to 5 per cent, and correspondingly increasing the grain. Otherwise the experiment was continued to completion, covering 126 days.

[1] Owing to the fact that one of the pigs in this lot proved inferior, the results were discarded.

Results of the Experiment.

Rations, Food Consumption, Daily Gain, Dry Food Required to Produce Gain, and Cost of Gain.

Lot.	Ration.	Dry Food consumed (Pounds).	Daily Gain (Pounds).	Dry Food required to Produce 100-pound Gain.	Cost of 100-pound Gain.
I	Grain only	702.92	.95 .96	293	$7 22
II	Grain+tankage	758.18	1.10 .87	311	8 55
III	Grain+"semi-solid" buttermilk	812.96	1.07 .92	327	14 47
IV	Grain+"semi-solid" buttermilk	924.46	1.22 1.09	319	18 91
VI	Grain+dried buttermilk	899.40	1.27 1.43	264	13 16

It is evident from the above data that, while the buttermilk products as a component of the ration aided in growth, their cost is too great to render their use financially advisable.[1] Pigs on the grain plus ash mixture made a very good growth, and must have found at least a fair amount of growth accessories (vitamins) in the ration fed.

Note. — Considerable quantities of evaporated buttermilk and skim milk are used in growing poultry. It is undoubtedly very efficient, furnishing mineral matter, desirable proteins and vitamins; and probably its use in reasonable amounts is economical in forcing pullets to early egg production. The writer, however, has no data on this subject. Other things being equal, the dried product should prove more economical than that which has only a portion of the water removed.

Lactic Acid — Its Value in Promoting Growth in Pigs.

The claim has been made that the addition of dilute lactic acid — the acid of sour milk — to the grain slop fed to pigs will improve the appetite and digestion and promote an increase in growth. Two trials were made to demonstrate the truth or fallacy of the claim.

Trial I, May 19–September 8.

Two lots of two pigs each (averaging 30 pounds each in weight) were placed in two separate pens and fed as follows:

Lot I. — Six ounces of corn meal to each quart of skim milk, in sufficient amounts to satisfy the appetite. When the lot reached a daily consumption of 72 ounces of meal and 12 quarts of skim milk, the ration was increased by the addition of the following mixture, in the proportion of 9 ounces to each quart of water:

28 pounds Corn meal.
28 pounds Wheat middlings.
28 pounds Ground oats.
16 pounds Digester tankage.

After the animals had reached a weight of about 100 pounds each, the skim milk was reduced to 8 quarts daily for the lot, and was supplemented with a grain

[1] The use of small amounts of "semi-solid" or dried buttermilk, or of dried skim milk may be worth while from the time young pigs are weaned until they attain a weight of 25 to 30 pounds, when the natural product is not available.

mixture of one-third each of corn meal, wheat middlings and ground oats to satisfy appetites. This was continued until the end of the trial. This ration, with its variations, was considered a standard or check ration suitable for promoting normal growth.

Lot II. — The same corn meal, middlings, oats and tankage mixture fed to Lot I. This was fed throughout the trial in the proportion of 9 ounces to each quart of water containing .7 per cent of lactic acid. Milk was omitted from the ration.

Food Consumed and Growth Produced (Pounds).

	Lot I. Pigs 1 and 2.	Lot II. Pigs 3 and 4.
Number of days in trial	116	116
	Pounds.	Pounds.
Dry Matter in food consumed:		
Skim milk[1]	199.0	none
Corn meal	336.4	164.0
Wheat middlings	140.2	167.0
Ground oats	140.2	167.0
Digester tankage	4.8	76.0
Lactic Acid[2]	none	18.0
Total	820.6	592.0
Growth Produced:		
Weight at beginning	35 26	28 29
Weight at end	165 175	122 120
Total gain	130 149	94 91
Daily gain	1.12 1.28	.81 .78
Dry Matter per 100 pounds Gain	294.1	320.0

[1] Pigs 1 and 2 received 1,028 quarts of skim milk averaging 9 per cent solids. One quart was taken to equal 2.15 pounds.

[2] Pigs 3 and 4 received 1,224 quarts of water containing .7 per cent lactic acid. One quart was taken to equal 2.1 pounds.

A glance at the above table shows that Lot I, which received considerable skim milk in addition to the grain mixture, made a satisfactory growth. This may be attributed, in part at least, to the ease of digestion and assimilation of the milk, to the extra dry matter consumed, to the favorable proteins and also to the vitamin content of the milk. Lot II grew fairly well, but the pigs were not equal to Lot I because of the absence of the skim milk. The lactic acid did not seem to be helpful in growth production.

Trial II, September 22–December 1.

Six grade Chester White pigs were procured in September and fed upon skim milk and corn meal until each weighed between 20 and 30 pounds. They were then divided into three lots of two each and fed as follows:

Lot I. — Eight ounces of the following mixture to each quart of water, in amounts to satisfy the appetite:

30 pounds Corn meal.
30 pounds Wheat middlings.
30 pounds Ground Oats.
10 pounds Digester tankage.

Lot II. — The same grain mixture as Lot I, with sufficient lactic acid added to the water so that it tested .4 per cent of that ingredient.

Lot III. — The same grain mixture as Lots I and II, with sufficient lactic acid to make the solution test .8 per cent of that ingredient.

The experiment began September 22 and ended December 1, proceeding without any disturbances. The weighing, housing and general care of the pigs were the same as in the preceding experiments. For the first two weeks of the experiment, after the change was made from the corn meal and skim milk to the experimental diet, none of the pigs made much growth; but as soon as they adapted themselves to the new diet a reasonable growth was noted from week to week.

Dry Matter in Food Consumed and Growth Produced (Pounds).

	Lot I. Pigs 1 and 2.	Lot II. Pigs 3 and 4.	Lot III. Pigs 5 and 6.
Number of days in trial	70	70	70
	Pounds.	Pounds.	Pounds.
Dry Matter in food consumed:			
Corn meal	79.4	77.8	79.4
Wheat middlings	80.2	78.6	80.2
Ground oats	80.8	79.2	80.8
Digester tankage	27.2	26.8	27.2
Lactic acid	none	5.0[1]	10.4[2]
Total	267.6	266.2	278.0
Growth Produced:			
Weight at beginning	29 28	21 21	25 23
Weight at end	67 66	62 57	60 65
Total gain	38 38	41 36	35 42
Average daily gain	.54 .54	.59 .51	.50 .60
Dry Matter per 100 pounds Gain	351.3	345.7	361.0

[1] Pigs 3 and 4 received a total of 604 quarts each of water containing .4 per cent lactic acid, 2.1 pounds per quart.

[2] Pigs 5 and 6 received a total of 616 quarts each of water containing .8 per cent lactic acid, 2.1 pounds per quart.

From the general appearance of the pigs, and from the above data, one is justified in concluding, in case of both trials, that the lactic acid was without any pronounced effect in promoting growth. It is possible that lactic acid may have some therapeutic effect in case of animals undergoing digestive disturbances, but under normal conditions its use is not advised.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 218 OCTOBER, 1923

THE

CONTROL OF THE SQUASH VINE BORER IN MASSACHUSETTS

By HARLAN N. WORTHLEY

The squash vine borer is a widely distributed and very serious enemy of squashes and related plants. Because of the protected life of the larva, which burrows within the squash stem, insecticides have been considered useless in the control of this pest. The best direct remedy has been to cut the borers from infested vines, a tedious and impractical treatment in commercial plantings.

This bulletin reports the discovery and application of a spraying program for squash vine borer control which has given satisfactory results under Massachusetts conditions, and which kills the insect in the egg stage, thus protecting the plants against the slightest injury from borers.

Publication of this Document approved by the Commission on Administration and Finance

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

THE CONTROL OF THE SQUASH VINE BORER IN MASSACHUSETTS.

BY HARLAN N. WORTHLEY.

Distribution and Importance.

The squash vine borer [1] is a native of the New World, and apparently is of tropical origin. It has spread northward over that portion of the United States east of the Rocky Mountains, and into Southern Canada. It is found as far south as Argentina.

In many localities the squash vine borer is the most serious enemy of winter squashes. Pumpkins and summer squashes are also affected, and more rarely melons and cucumbers.

Description.

Egg. — The egg of the squash vine borer is shown in Plate I, figure 1 and Plate II, figure 2. It is about one-twenty-fifth of an inch in length, and is of a dark reddish brown color. As may be seen in Figure 1, the eggs are not laid in clusters, as in the case of the squash bug eggs, but singly. Magnification, as in Plate II, figure 2, shows the chorion to be finely reticulated into tiny hexagonal figures.

Larva. — The larva, or "borer" (Plate I, figure 1 & Plate II, figure 3) as it is commonly called, is a fleshy, white, nearly hairless caterpillar with a black head and a dark brown to black thoracic shield. When full grown it measures about an inch in length. Newly-hatched larvae, which are commonly not detected in the field, are about one-sixteenth of an inch long, sparsely covered with hairs, and with a broad black head, from which the white body tapers away to the anal extremity. In appearance the borer is quite distinct from the larva of the striped cucumber beetle, with which, however, it is often confused. The latter is but three-tenths of an inch long and is very slender, with the head and anal plate dark brown.

Pupa. — The pupa (Plate I, figure 1) is contained in an earth-covered cocoon of very tough, black silk about three-fourths of an inch long. The pupa itself is about five-eighths of an inch long, and is of a dark shining brown color. The head bears a horn-like process between the eyes, and the abdomen bears circles of hook-like spines.

Adult. — The adult moth (Plate I, figure 1) is five-eighths of an inch or more in length, with a wing spread of an inch to an inch and a half. It is strikingly beautiful, with long narrow olive green fore wings, bearing a fringe of blackish hairs at the tips. The hind wings are transparent, bearing scales only along the veins. The abdomen is covered with red or orange scales, and is marked with transverse white lines and a longitudinal row of black or bronze-colored spots. The tarsi are banded with white, and the hind legs are covered with long black, white, and orange-colored hairs. The sexes are quite similar, the male being more brilliantly marked than the female, and with a narrower abdomen.

Life History and Habits.

The squash vine borer passes the winter as a full-grown larva. It is enclosed in the tough silken cocoon which it spins in the soil of squash fields, at a depth of from one to six inches below the surface of the ground. Pupation occurs within this cocoon in the spring, and lasts about three weeks. At the end of this time the pupa cuts through one end of the cocoon by means of the horn-like process on its head, and wriggles to the surface of the ground, being aided in this endeavor by the circles of spines around its abdomen. When it projects above the ground about three-fourths its length, motion ceases, and very shortly the pupal skin splits back from the head and the adult moth slowly drags itself forth. The emergence occupies in the neighborhood of five minutes, when the freed moth climbs upon some nearby object to expand and dry its wings in readiness for flight, which can be accomplished in a matter of fifteen minutes following emergence.

Plate I, figure 1, is a record of continuous observations from 1920 to 1923,

[1] *Melitta satyriniformis* Hübner (Lepidoptera, Ægeriidæ).

PLATE I.

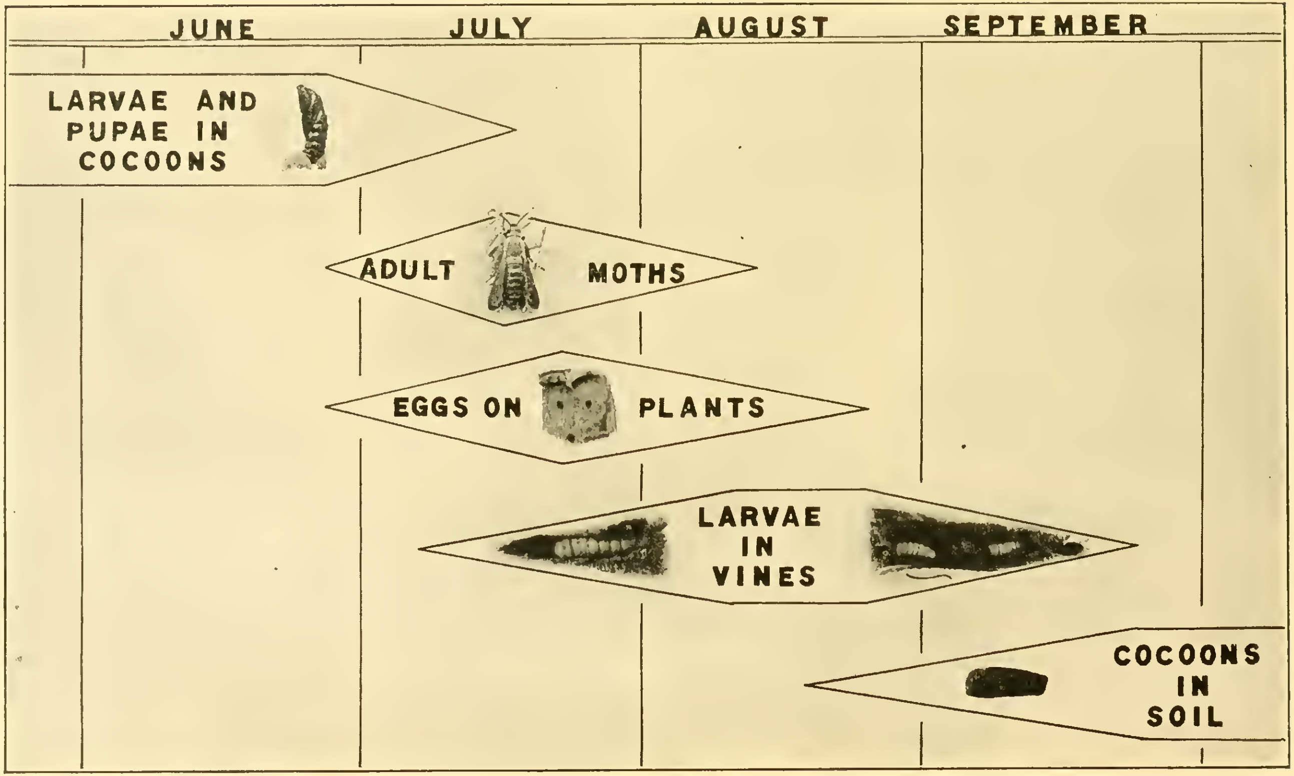

Fig. 1. Seasonal History of the Squash Vine Borer at Amherst.

and indicates an average seasonal occurrence of the different life stages of the insect at Amherst, and the average period of greatest abundance. The moths are present in numbers from the last of June until the first week in August. They dart from plant to plant in the heat of the day, and their rapidly vibrating wings and brilliant coloration cause them to be easily mistaken for wasps. They are fairly strong flyers, and the writer has known them to locate squash fields removed one-half mile from where cucurbits were grown the previous year.

The female moths lay their eggs singly, going from hill to hill, depositing one to several eggs on each plant. The eggs are attached by the flattened base, and are held in place by a cement-like secretion. Individual moths seem to have different tastes regarding the location selected for the eggs. In following moths from hill to hill, some are observed to seek the junction of the stem and the ground, some oviposit upon the leaf-stalks, and some even tuck the eggs down between the squash stem and the surrounding soil. Other moths lay their eggs indiscriminately upon main stem, leaves, leaf-stalks, and even upon tendrils and blossoms. The favorite location, however, appears to be the main stem near the base. Several counts have been made to determine the percentage of the total number of eggs laid on the different parts of the plant. The data are presented in Table I.

Table I. — *Location of Squash Vine Borer Eggs.*

	On Stem.	On Leaf-stalks.	On Leaves.	Total.
Lexington, 1922	377	299	10	686
Amherst, 1922	168	48	0	216
Littleton, 1923	48	5	7	60
Amherst, 1923	426	36	23	485
Total	1,019	388	40	1,447
Per cent of total	70.4	26.8	2.8	

Individual moths may lay as many as one hundred fifty to two hundred eggs. Theoretically, therefore, ten moths only, flying from plant to plant and each laying a total of one hundred fifty eggs, are necessary to cause a one hundred per cent infestation of fifteen hundred plants, which is perhaps the average number of plants per acre.

Eggs are to be found from late June or early July until mid-August, and even later in some seasons. The period spent in the egg stage has been placed by various investigators at from six to fifteen days. Breeding records at Amherst show a variation of from nine to thirteen days, but they are not extensive and may not represent the extremes for this climate.

Table II. — *Length of Egg Stage, Amherst.*

Number of Eggs.	Eggs laid.	Eggs hatched.	Number of Days.
10	July 29, 1920	Aug. 11, 1920	13
4	Aug. 4, 1923	Aug. 13, 1923	9
1	Aug. 5, 1923	Aug. 14, 1923	9

The records are those obtained from eggs laid by confined moths. Eggs collected in the field showed a high percentage of parasitism, which is discussed in another section of this paper, and were quite unsatisfactory for rearing.

When emerging from the egg, the young larva chews a ragged hole in one end and crawls forth upon the surface of the squash plant. Its subsequent action shows considerable variation in habit. In many cases it burrows directly into the host tissue. In other instances newly-hatched larvae have been seen to crawl to distances of eight to ten inches from the egg-shell, feeding here and there on the leaf or stalk before finally tunneling out of sight. Those which invade the leaf-stalks and main leaf veins gradually work their way toward the main stem. Since the average squash plant has not put forth runners when the majority of the eggs have been laid, the result of this movement is a concentration of injury in the main stem near the base.

The burrow made by the squash vine borer larva is a twisting one, and is frequently obstructed by a webbing of silk mixed with yellowish grains of excrement, called "frass". The greater part of the frass is pushed out through holes in the stem, where it clings in moist masses, serving to indicate the position of the borer within. The popular opinion seems to be that borers penetrate directly to the central cavity of the main stem along which they work, feeding at the walls of this cavity. This is not strictly the case. The larvae usually work in the tissue surrounding the central cavity of the stem, and often do not break through into this cavity until they are about half grown.

One borer can usually find food for its complete development at the base of the stem. When more borers are present, however, the mining is extended along the main stem and runners, into the bases of the leaf-stalks and, in rare instances, even into the fruit itself. Upon the death of one plant, the larvae are able to transfer their activities to one nearby.

Growth is completed in a month to six weeks, at the end of which time the full-grown caterpillar deserts its burrow in the squash plant and enters the soil nearby. After penetrating to a depth of from one to six inches it hollows out a cell, spins its cocoon of tough black silk and, gradually shrinking within its last larval skin, settles down to pass the winter.

There is but one generation of the squash vine borer each year in New England. It is partially double-brooded, however, in the latitude of New Jersey and Southern Ohio and two full generations occur in Georgia and further south.

Nature of Injury.

In late July in Massachusetts, squash growers begin to notice plants with wilted, drooping leaves. This condition may be the result of excessive feeding in the root by larvae of the striped cucumber beetle. It is also a symptom of the disease known as bacterial wilt. The chief cause of this wilting, however, is found in the gradual destruction of the main stem of the squash plant near its base by the tunneling of squash vine borer larvae, which may be detected by the yellowish masses of frass which they push from their burrows.

The base of the main stem frequently fails to support all the borers present, and becomes a filthy, rotting mass, invaded by various sap-feeding beetles and filth-loving insects. See Plate II, figure 4. It is finally reduced to a few dried shreds, separated from the root by a light pull. See Plate II, figure 5.

The effect of squash vine borer infestation varies from a slight check in the growth and productiveness of the infested vine, to its death outright, and the loss of its partly-formed fruit. In the same field one may see a well-grown, thrifty vine which shows some borer injury, and nearby a dried, withered remnant of a vine, the shredded and distorted base and hardened masses of frass testifying to the cause of its death. A combination of factors is involved in this difference in the effect of infestation. First, a thrifty vine can often support one or two borers, while a less vigorous plant will be completely girdled. Second, plants which have been girdled do not always die. If the runners have developed far enough to "strike" numerous secondary roots from the nodes, and if these roots can find sufficient moisture and food, the vine may yet produce a fair crop. The crop is materially reduced, however, if not lost entirely in dry portions of the field or in dry years, or when fertilization of a naturally poor soil has been confined to the hill, as is so often the case. In the case of squashes planted late, or having a slow early growth, in which the runners have failed to root before the borers become half grown, the crop is very often a failure.

Natural Enemies.

No parasitic enemies of the adult moth have yet been recorded. It is the chance prey, however, of certain large robber flies (Asilidae) which have been observed to pounce upon the moths in the fields. The larvae in their tunnels in the squash stem appear to have escaped parasites, but are sometimes attacked by the larvae and adults of ground beetles (Carabidae). These agencies are of little economic importance.

The eggs of the squash vine borer are subject to a high degree of parasitism by a tiny wasp of the family Scelionidae, the members of which are exclusively egg parasites. The species has been identified by Mr. A. B. Gahan, of the

PLATE II.

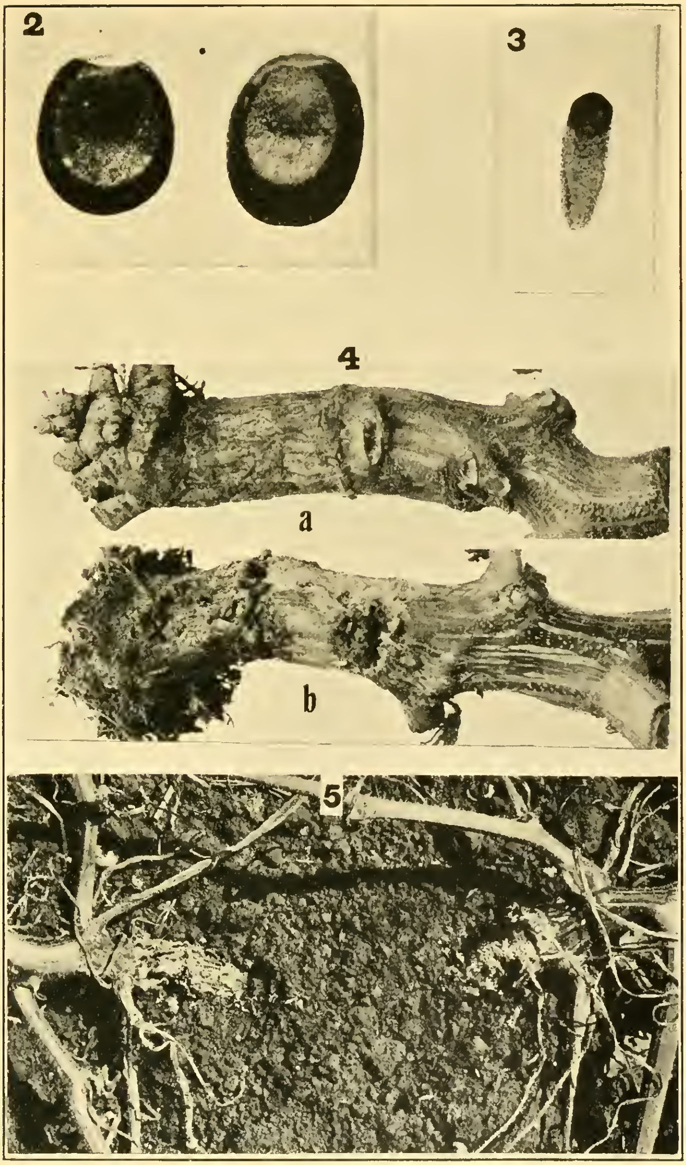

Fig. 2. Photomicrograph of squash vine borer eggs, x 24 (original).
Fig. 3. Newly hatched squash vine borer larva. Photomicrograph, x 13 (original).
Fig. 4. *a*. Healthy squash stem. *b*. Badly infested squash stem. Note burrows at "X." (Photo by R. L. Coffin.)
Fig. 5. Center of badly infested hill of squash. Note shredded condition of the bases of the stems. (Photo by R. L. Coffin.)

United States National Museum, as *Telenomus* (*Prophanurus*) sp. The extent of the work of this tiny benefactor is evident from the following records of rearings.

TABLE III. — *Parasitism of Squash Vine Borer Eggs.*

Date.	Eggs.	Parasites.	Per Cent of Parasitism.
1920			
July 24	11	11	100
July 31	20	9	45
1922			
July 7	6	2	33.3
July 28	8	1	12.5
1923			
July 16	52	40	77

CONTROL.

Cultural and Hand Methods.

Insecticides have heretofore been considered useless in the control of the squash vine borer, and consequently many cultural practises and hand methods have been advanced for the purpose of lessening the severity of the attack. A few of these are applicable under Massachusetts conditions, and are here discussed.

Trap Crops. — Winter squash, summer squash, pumpkins, melons, and cucumbers seem to be visited in the above order of preference by the egg-laying moths. Plantings of winter squash or summer crooknecks may draw the moths away from other cucurbits, and when used for this purpose should then be destroyed before the borers in them become full grown.

Fall Plowing. — Although many larvae doubtless penetrate below the plow line before spinning their cocoons, others are turned up, crushed, or exposed to the winter weather when squash fields are plowed in the fall following the removal of the crop.

Fertilization. — Many farmers seek to grow squashes on poor land with no application of fertilizer except in the hill. Borer damage is sometimes greatly enhanced by this practice. A note made by the writer in 1920 shows the effect of adequate fertilization, and is here quoted:

The history of the squash crop this year is a good illustration of the effect of proper preparation of the land and care of the crop during early growth in offsetting the attack of the squash vine borer. The experimental plot was a sandy loam. In the spring a thirty-inch stand of rye had been plowed under. Lime was applied at the rate of three thousand pounds per acre, and a 4–8–4 fertilizer at the rate of fifteen hundred pounds per acre. At planting, double furrows were opened up ten feet apart, and a good big forkful of manure was dropped every eight feet in the furrows. Over this manure, the seeds were planted. From the time the plants appeared until the runners closed the spaces between the rows, the ground was kept mellow by frequent cultivation. Before the plants started to run they were thinned to two plants in each hill. High fertilization and mellowness of soil promoted vigorous growth and the formation of secondary roots from the nodes of the runners. This formation of secondary roots was favored also by the unusually even distribution of rainfall throughout the summer. The importance of these secondary roots can be judged by the fact that every plant in the field was infested with borers, and the great majority suffered a complete rotting off of the main stem as a result. In spite of this, the harvest of squashes was declared to be satisfactory.

Covering the Runners. — Some growers make it a practise to insure the "striking" of secondary roots by covering the runners with earth at about a foot from the base of the plant. Fertilizer is sometimes added at these points. This practise is a useful one, and often serves to reduce materially the amount of damage done by the borers.

Cutting out the Borers. — The practises mentioned above, while they often aid in mitigating the severity of the squash vine borer attack, have no direct effect upon the borer itself. The best method heretofore practised for actually killing the borers has been the custom of cutting them from the vines. Slitting the stem lengthwise in both directions from the frass-clogged hole and bending back the cut portion will usually reveal the borer, which can then be removed and killed. If the stem is subsequently covered with earth, the operation will have little injurious effect upon the plant. By constant watchfulness from the middle of July to the first of September, a few plants in a home garden can be protected from excessive borer injury by this means.

The Use of Insecticides.

Certain insecticides have been tried in the past against the squash vine borer, and have been declared valueless. Among these were arsenate of lead painted thickly on the squash stems, and wrappings of tarred paper. Injections of various toxic substances have been tried at this station, but without success, both because of the nature of the burrows and of the webbing of silk and frass which obstructs them. Studies of the life history and habits of the species in 1920 led to spraying experiments in 1921 with the following materials: —

Material.	*Possible Action.*
Arsenate of lead powder, 3 pounds in 50 gals. water.	Poisoning of newly-hatched larvae.
Nicotine sulfate (Black-leaf "40"), 1 part in 100 parts of water.	Penetration and killing of the eggs — repelling of adult moths.
Bordeaux mixture, 4–4–50 formula.	Repelling of adults.

Preliminary experiments with these materials were conducted in 1921 and 1922 leading up to the successful field applications of 1923. On the basis of this work, the following sprays were applied in 1923: —

Material.	*Action of Spray.*
Black-leaf "40", 1–100, 1–250, and 1–500.	Toxic to eggs.
Arsenate of lead powder, 2 pounds in 50 gals. water; 3 pounds in 50 gals. water, plus "Kayso" sticker.	Poisons newly-hatched larvae as they chew at surface of squash plant.

The work was done on a commercial scale at Littleton, in coöperation with a squash grower, and at the Agricultural Experiment Station at Amherst. It is here reported in some detail.

The Littleton Experiment. — Mr. Homer Richards, a truck gardener and orchardist living in Littleton, offered the use of a one-acre field of winter squashes and, in addition, his assistance in the application of the sprays. The field contained twenty rows planted fifteen feet apart, and twenty-five hills six feet apart in each row. Plots were marked off as follows: —

Rows.	Treatment.	Rows.	Treatment.
1–2	Check	13–14	Check
3–6	Black Leaf "40", 1–500	15–18	Black Leaf "40", 1–100
7–8	Check	19–20	Check
9–12	Lead Arsenate, 2.5–50		

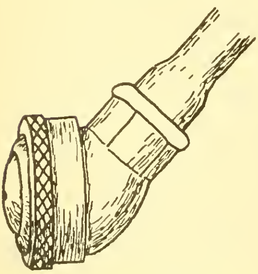

Fig. 1. — 45° Angle-disc Nozzle Used in the Experiments.

Four applications were made: on July 5, July 12, July 19, and July 26. Compressed air sprayers of three gallon capacity were used for the first three applications. Each was fitted with a short spray rod and a 45° angle disc nozzle, pictured in figure 1. All portions of the plants were thoroughly sprayed, particular attention being paid to the base of the stem. The fourth application was made with a power sprayer and one lead of hose bearing the short spray rod and angle nozzle. A pressure of 100 to 125 pounds per square inch was maintained.

Examinations to check the progress of the infestation and the effect of the treatment were made by the writer on each trip to Littleton. On July 13, a count of eggs on about twenty-five plants in each treatment gave the following results: —

Table IV. — *Squash Vine Eggs at Littleton, July 13, 1923.*

Treatment.	Eggs per Plant.
Check	1.04
Black Leaf "40", 1–500 .	.77
Lead Arsenate, 2.5–50 .	.94
Black Leaf "40", 1–100 .	.80

The difference in number of eggs exhibited by the check and treated plots is attributed to the mechanical effect of the spray in knocking some eggs from the plants. The writer has noticed frequently that while some eggs are firmly attached to the plants, others may be dislodged at a touch. The difference exhibited between the lead arsenate treatment and the Black-leaf "40" is attributed to a possible slight repellent effect of the nicotine sprays, the odor of which can be detected on the vines for about twenty-four hours following their application.

The effectiveness of the treatments was determined by counts of the number of borers and number of plants in treated and check plots. The final count was made on August 13 and 14, at which time the oldest larvae were ready to leave the vines, and the youngest ones were large enough to make their presence known. Every plant in the experimental field was carefully examined for borer injury, and the number of plants and number of borers in each hill recorded. The detailed results of this count are given in Table V. A summary of these counts, translated into borers per thousand plants, is also given.

Table V. — *Effectiveness of Treatments, Littleton, 1923.*

Treatment.	Rows.	Number of Plants.	Number of Hills.	Number of Infested Hills.	Number of Borers.
Check	1–2	221	50	50	326
Black-leaf "40" 1–500	3–6	387	100	81	162
Check	7–8	187	50	50	148
Lead arsenate, 2.5–50 .	9_12	335	100	69	130
Check	13–14	132	50	46	134
Black-leaf "40", 1–100	15–18	375	100	18	18
Check	19–20	159	50	47	126

Summary.

Material.	Borers per Thousand Plants. Check.	Treated.	Per Cent of Control.
B. L. "40", 1–100	910	48	94.8
B. L. "40", 1–500	1,138	420	63.1
Lead arsenate, 2.5–50	909	388	57.4

The Amherst Experiment. — The experimental field at the Massachusetts Agricultural Experiment Station contained twenty-eight rows, twelve feet apart, with nine hills, eight feet apart in each row. Each treatment was applied to each of three separate plots, and each treated plot was flanked by a check plot with which its infestation was compared. The plan was as follows: —

Rows.	Treatment.	Rows.	Treatment.
1–2	Check	15–16	Black Leaf "40", 1–250
3–4	Black Leaf "40", 1–100	17–18	Lead Arsenate, 3–50
5–6	Black Leaf "40", 1–250	19–20	Check
7–8	Check	21–22	Black Leaf "40", 1–100
9–10	Lead Arsenate, 3–50	23–24	Black Leaf "40", 1–250
11–12	Black Leaf "40", 1–100	25–26	Check
13–14	Check	27–28	Lead Arsenate, 3–50

Four applications were made: — on July 7, July 17, July 23, and August 2. The first application was made with a compressed air sprayer, and the other three with a power outfit. Before the last application it was found necessary to move some runners from the path of the spray rig as it passed between the rows.

On July 24, a count of eggs and larvae present in the different plots gave the following results: —

TABLE VI. — *Status of Infestation, Amherst, July 24, 1923.*

TREATMENT.	Eggs per 100 Plants.	Eggs already Hatched.
Check	41	17+
Black Leaf "40", 1–100	16	0
Black Leaf "40", 1–250	19	0
Lead Arsenate, 3–50	16	3+

The difference in the number of eggs found in the checks and in the treated plots is greater here than at Littleton (see Table IV). This difference is doubtless due to the greater force with which the spray stream is applied with a power sprayer than with a compressed air sprayer. It seems clear that the difference is due to the mechanical action of the spray stream in knocking eggs from the plants rather than to any marked repellent qualities of the spray materials themselves. Lead arsenate has not been demonstrated to be repellent to insects, and yet no more eggs were found in the plot sprayed with this material than in the plots treated with the nicotine sprays. In view of this fact, it is impossible to attribute definite repellent qualities to the Black-leaf "40", in this connection.

The number of larvae found compared with the number of eggs present, as expressed in the last column of the table, indicates the toxic effect of the spray materials. The counts in the check plots may be taken as a normal progression of development of the eggs. The counts in the plot treated with lead arsenate indicate a kill of about 50 per cent, while those in the plots treated with both strengths of Black-leaf "40" indicate 100 per cent control.

The final count was made on August 20 and 21. The detailed results are recorded in Table VII, and are summarized below.

TABLE VII. — *Effectiveness of Treatments, Amherst, 1923.*

TREATMENT.	Rows.	Number of Plants.	Number of Hills.	Number of Infested Hills.	Number of Borers.
Check	1–2	65	16	13	33
Black-leaf "40", 1–100	3–4	61	18	2	2
Black-leaf "40", 1-250	5–6	69	18	7	9
Check	7–8	82	18	18	82
Lead arsenate, 3–50 .	9–10	70	18	10	19
Black-leaf "40", 1–100	11–12	55	18	0	0
Check	13–14	39	17	16	32
Black-leaf "40", 1–250	15–16	69	18	3	3
Lead arsenate, 3–50 .	17–18	63	18	7	10
Check	19–20	61	18	17	58
Black-leaf "40", 1–100	21–22	69	18	0	0
Black-leaf "40", 1–250	23–24	76	18	7	8
Check	25–26	66	17	14	36
Lead arsenate, 3–50 .	27–28	54	18	7	12

Summary.

	Borers per Thousand Plants. Check.	Treated.	Per Cent of Control.
BLACK-LEAF "40", 1–100.			
Rows 3–4	481	33	93.2
Rows 11–12	837	0	100.0
Rows 21–22	953	0	100.0
Average	757	11	97.7
BLACK-LEAF "40", 1–250.	Check.	Treated.	Control.
Rows 5–6	995	131	86.9
Rows 15–16	837	43	94.9
Rows 23–24	547	53	90.4
Average	793	76	90.5
LEAD ARSENATE, 3–50.	Check.	Treated.	Control.
Rows 9–10	995	280	71.9
Rows 17–18	953	159	83.4
Rows 27–28	547	223	59.3
Average	832	221	73.5

The high degree of effectiveness exhibited by Black-leaf "40" at the above dilutions is undoubtedly due to its ovicidal action, since, as shown in Tables VI and VII, eggs were found in the plots treated with these materials in great excess of the numbers of larvae found later in the same plots. Substantiation of these observations has been sought by laboratory tests.

In these tests Black-leaf "40" at the strengths of 1–100 and 1–250 killed all the eggs which were not parasitized. It is interesting to observe that Black-leaf "40" does not destroy the egg parasites. Parasitized eggs included in the experiments yielded the adult wasps even when sprayed with the greatest strength of Black-leaf "40".

Recommendations. — The experiments here recorded indicate that almost complete relief from squash vine borer attack can be gained by four applications in July of Black-leaf "40" at a strength of 1 part in 100 parts of water, where the applications are made with a power sprayer. At the same strength, the material is over 90 per cent effective applied with a low-pressure, small-capacity outfit such as the compressed air sprayer. Applied at a strength of 1 part in 250 parts of water with the aid of a power sprayer, the material is also over 90 per cent effective. Lead arsenate gives too small a percentage of control to warrant its use.

On the basis of the experimental evidence, the following recommendations are made for the use of nicotine sulfate against the squash vine borer.

1. If a compressed air sprayer, knapsack pump, or other small capacity, low-pressure outfit is to be used, apply Black-leaf "40" at the rate of 1 part in 100 parts of water (1.3 fluid ounces per gallon) making 4 applications, one week apart in July.
2. If a machine capable of maintaining a pressure of 100 to 150 pounds per square inch is to be used, such as a good barrel pump or a power outfit, apply Black-leaf "40" at the rate of 1 part in 250 parts of water (3.2 pints in 100 gallons), making 4 applications, one week apart in July.
3. In spraying, be sure to drench all sides of the stem at the base. See that the leaf-stalks, and the under and upper surfaces of the leaves are thoroughly sprayed. When the plants have started to run, it is hardly necessary to spray the runners beyond three or four feet from the center of the hill.
4. Thorough spraying will largely free the sprayed fields from borers. Extermination may then be made complete by an examination of the plants in mid-August, cutting out those borers that have escaped the spray.

Spraying may be begun during the first week in July. It would be better, however, to examine a few plants closely every day during the last week in June, in order to discover the first eggs. The first spray should be applied not later than a week after eggs are discovered.

Cost of Treatments Versus expected Profits.

Nicotine sulfate is a relatively expensive insecticide, and any spraying operation using this material at a strength of one part in one hundred parts of water, or one part in two hundred fifty parts of water, is a costly treatment, which will be quite likely to prove impractical under certain conditions of squash culture (*i.e.,* where the squash vine borer is not a serious pest).

The expense of treatment can be materially reduced by following the suggestions given below.

1. To facilitate spraying squashes, plant in wide rows with the hills close together in the row. This type of planting allows free passage of the spray rig between the rows, and little time is lost in stepping from hill to hill.
2. Thin to the desired number of plants in each hill as early as is compatible with good farm practise. In this way, no spray material is wasted on plants that are later to be destroyed.
3. Equip the four-foot spray rod with a 45° angle disc nozzle with a small hole in the disc. This breaks the spray up into a very fine mist which covers quickly and thoroughly with a minimum of waste. In addition, equip the base of the spray rod with an automatic shutoff of the spring-grip type, so that the stream can be stopped instantly, thus allowing no wastage when passing between hills. This type of equipment can be used as well with a compressed air

sprayer or one of the knapsack type as with a barrel pump or power outfit. With a power outfit, regulate the pressure at from 100 to 150 pounds per square inch.

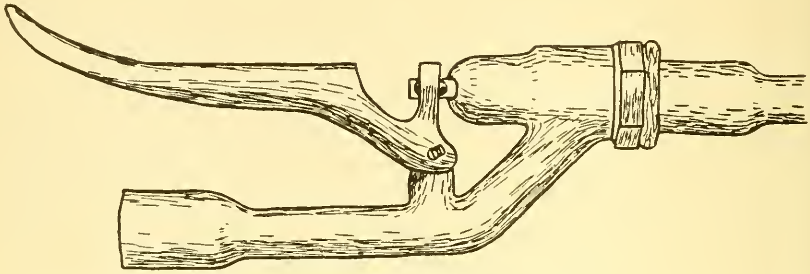

Fig. 2.— Automatic Shutoff Used in Experiments.

What may be called the average cost of spraying squashes has been figured from the records kept of the experimental work. The cost per acre can be seen to vary enormously, depending on the type of planting (hills per acre and plants per hill) and the stage of growth of the plants during the period of spraying. The figures given below are for four treatments, one week apart in July, applied to an acre containing one thousand squash plants of average growth.

1. Using compressed air or other small capacity, low-pressure outfit. Black-leaf "40", 1–100 recommended.

Dilute spray material, 150 gallons containing Black-leaf "40", 1.5 gallons at $12.50	$18 75
1 man, 24 hours at $.40	9 60
Total cost per acre of one thousand plants	$26 55

2. Using a barrel pump or power outfit giving a fairly large delivery at 100 to 150 pounds pressure. Black-leaf "40", 1–250 recommended.

Dilute spray material, 275 gallons containing Black-leaf "40", 1.38 gallons at $12.50	$17 25
3 men — 1 horse, 6 hours at $1.55	9 30
Total cost per acre of one thousand plants	$26 55

If the type of planting calls for more than 1,000 plants per acre, the cost of treatment is increased accordingly.

In an effort to discover the average increase in yield which might reasonably be expected from the use of the above treatment, and the relation of the value of this increase to the cost of treatment, letters were sent to prominent squash growers in various parts of the State. The replies received from those portions of the State where the borer is well established have been tabulated as follows:

Table VIII. — *Average Expected Increase in Yield of Winter Squashes.*

	Average Yield Per Acre (Tons).	Estimated Per Cent Increase from Borer-free Plants.
1	–	100
2	8.0	20
3	12.0	5
4	–	100
5	8.5	10
6	3.0	50
7	8.5	30
8	6.0	60
9	10.0	10
10	5.0	200
Average	7.6	59.5

The average increase thus estimated is 4.5 tons per acre. The average wholesale price of winter squashes during the sales-from-harvest period, September 1 to November 15, appears to be $.03 per pound or $60 per ton.[1] The value of the expected average increase of 4.5 tons per acre is therefore $270. Subtracting from this figure the cost of treatment leaves an estimated average net profit of from $241.65 to $243.45 per acre.

Summary.

The squash vine borer is a serious native enemy of winter squashes and related plants, for which no adequate remedy has previously been devised. The adult insect is on the wing during July, laying its tiny, reddish eggs upon the squash plants. The borers developing from these eggs cause the vines to droop and die by tunneling in the stem and girdling the plant, throwing masses of yellow frass out through holes in the stem, and causing the stem to rot. These larvae leave the vines in the fall, and spin cocoons in the soil. A number of cultural practises, such as fall plowing of infested fields, adequate fertilization to promote growth and to aid the secondary roots, and covering the runners with earth, have been recommended, as has the practise of cutting the borers from infested vines.

Experiments at this Station indicate that nicotine sulfate (Black-leaf "40"), at the strength of 1 part in 100 parts of water, kills over 97 per cent of the eggs, and, at the strength of 1 part in 250 parts of water, kills over 90 per cent of the eggs. Spraying should be done four times, at weekly intervals beginning the first week in July, using the stronger dosage with compressed air sprayers or similar machinery, and the weaker dosage with barrel pumps or power sprayers. When thoroughly done, spraying will largely eliminate borers from the fields. Complete extermination is then possible by cutting out the remaining borers during the middle of August.

The treatment is estimated to cost between $25. and $30. per thousand plants. Thus intensive methods of culture and careful, economical spraying must be the rule where the treatment is to be found practicable on a commercial scale. However, estimates of various squash growers regarding the expected increase in yield from borer-free plants indicate an average net profit of over $200. per acre from the use of this treatment. For the home gardener, to whom cost of production is a small item, it offers a ready means of successfully fighting this most troublesome enemy of squashes.

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[1] Computed from the Boston Produce Market Reports, 1920–1923.

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